TRANSPORTATION DEPARTMENT

IDAHO

RESEARCH REPORT

FIELD EVALUATION OF THE PAT WEIGH-IN-MOTION SYSTEM

FINAL REPORT
ITD-RP095

to:

Idaho Transportation Department
Boise, Idaho

by

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Boise State University
Boise, Idaho 83725

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Boise, Idaho 83707

August 1986

ABSTRACT

A reliable system for accurate weighing of trucks at highway speeds offers attractive potential for statistical data gathering, screening trucks for weight limit enforcement, and more efficient use of Port of Entry facilities and personnel.

In a series of field trials from 1981 to 1983, ITD tested and evaluated the German made PAT Weigh-In-Motion system by recording data collected at highway speeds and comparing these data with static weights and measurements taken on the same trucks at the Bliss POE. Rigorous statistical analyses were conducted on data from the two major studies. While these studies did identify the more important operating variables. none of the statistical relationships demonstrated the precision necessary to use the models for predictive purposes.

Operating at highway speeds, the PAT system evaluated in this project did not provide individual axle weights and spacings of sufficient accuracy to serve as direct substitutes for POE static weights and measurements. The results of these studies should provide useful information regarding the limitations and possible application of Weigh-In-Motion technology.

ACKNOWLEDGEMENTS

John Hamrick provided valuable liaison between ITD and PAT and performed preliminary data sorting. He also directed the ITD data collection crew, along with Foreman Joe Sturtevant.

Richard Johnson of the California Department of Transportation furnished useful advice on system problems. ITD's Jerry Mansell provided editorial assistance.

This project would not have been possible without the help of work crews from ITD District 4, under District Engineer Howard Johnson and Assistant Maintenance Foreman Jack Morris, and the Port of Entry, under Supervisor Engene Herzinger.

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IDAHO TRANSPORTATION DEPARTMENT

IDAHO RESEARCH PROJECT NO. 95
PAT WEIGH-IN-MOTION SYSTEM

INTRODUCTION

The concept of weighing trucks at highway speeds is extremely attractive for purposes of statistical data gathering and as a means of screening trucks for weight limit enforcement. The potential benefits of a reliable weigh-in-motion system include decreased delays for most trucks, more efficient use of Port of Entry (POE) personnel, and more comprehensive traffic data for highway design and maintenance.

The objectives of Idaho Research Project No. 95 were to select, install, and test a Weigh-In-Motion (WIM) system and to determine if the WIM system could provide data of sufficient statistical accuracy to serve as direct substitutes for the POE static weights and measurements.

EQUIPMENT SELECTION AND INSTALLATION

The German-made PAT system was selected in 1978. The unique features of the PAT system were the thin weigh-plates and compact, shallow support frames. This allowed the weight elements to be installed in the pavement surface course, while other systems required separate concrete support blocks within the roadway.

The data system ordered from PAT was specified to include visual CRT display, paper printout, and data recording on magnetic tape cartridges. Among the data items to be furnished were axle weights, axle spacings, bumper-to-bumper distance, gross vehicle weight, and vehicle speed. In addition, the program was to automatically classify trucks by the number and grouping of axles, conforming to the Idaho weight limit law classifications.

In the fall of 1979, four PAT weigh-plates and the associated vehicle detector loops were installed in the right-hand lane of I-84 eastbound near Bliss, Idaho. This site was chosen because it was approximately one-half mile ahead of the permanent weigh station at Bliss, had a suitably straight and level alignment, and had an overpass structure for protection of the data recording equipment and for mounting cameras.

Appendix A includes a site layout diagram, photographs of the installation procedure, and a list of installation costs. (Because of the research potential offered by the project, PAT provided the complete system at a cost of $12,000, significantly below the market price of $65,000.) ITD and PAT personnel installed and maintained the equipment, and ITD personnel operated the system doing this project.

Until 1980, PAT had only one sales representative and no service organization in the U.S. Shipping and customs, the language barrier, unfamiliarity with U.S. electronic and data processing standards, and the specialized Idaho programming requirements all contributed to delays in delivery of the electronic equipment. Supplier service improved when PAT merged with Siemans-Allis, Inc., in 1980.

Equipment problems caused further delays in 1980 and 1981. Two of the weigh-plates, the CRT display unit, the operator's keyboard, the data tape recorder, and some computer circuit boards were repaired or replaced (at the supplier's expense) during early field trials. By April 1981, the quick-setting concrete patching material used for embedding the weigh-plate frames was failing under traffic and weather actions; two frames were removed and the bedding was repaired.

Late in 1981, ITD purchased an air-conditioned van and modified it to contain all the PAT electronic equipment for this project (and for the portable PAT weigh-plates used by ITD throughout the state), spare parts, tools, supplies, radios, and a gas-powered electric generator. The van also provided a safe, weather-protected observation position for the operators.

FIELD CALIBRATION

The system was ready for field calibration in February 1982. Using a three-axle truck with a gross weight of 30,000 pounds, multiple runs were made at speeds of 20, 40, and 60 mph. The weigh-plate calibration potentiometers were adjusted to minimize the differences between the PAT gross weights and the known static weight.

Calibration checks were made quarterly during the study period, and potentiometer adjustments were made as necessary. Appendix B contains calibration data from February 1982 and April 1983, and copies of the POE scales certifications.

DATA COLLECTION AND DATA ENTRY

Data collection at the PAT test site consisted of recording the input from the weigh-plates and detector loops and observations of the road surface condition, wind direction, and weather conditions. As vehicles in the normal traffic stream passed over the weigh-plates, the identities of randomly selected trucks were radioed ahead to POE personnel at the Bliss weigh station. These trucks were weighed on the static scales for comparison with the PAT dynamic weights. The selection procedure was not completely random, however, as trucks were omitted from the sample when:

1) trucks could not be properly identified at the Bliss weigh station;
2) the weigh station became congested, and the time required to measure and weigh each axle would have caused excessive delays for other truckers;

3) trucks were observed to miss one or more weigh pads;
4) trucks were observed braking or accelerating over the test section;
5) the steering axles were observed to cross either the left or right one-third of the weigh-plates, which should cause the trailing axles to miss the weigh-plates; or
6) tailgaters caused faulty axle classification.

Certain automatic self-checking features of the PAT system proved helpful during data collection and analysis. First, the two pairs of weigh-plates actually provided separate weighings of each axle. Large differences between the two weight measurements indicated possible equipment problems, and the operator was alerted by an error message. Similarly, large differences between left and right side weight measurements generated an error message. These features served as quality control checks and also helped the operator trace the source of occasional equipment problems.

An interface program allowed the data which was automatically collected on the field data tapes to be transferred directly to the mainframe at ITD Headquarters in Boise. The weigh station data and data from visual observations (wind, weather, etc.) were entered manually through a data terminal. The separate files were merged and the statistical analyses were made using a proprietary package of data manipulation computer programs.

INITIAL STUDY: FEBRUARY-JULY 1982

For one 24-hour period each month between February and July 1982, the field crew collected sample data for a comprehensive study of the PAT Weigh-In-Motion system. A total of 1,218 vehicles were sampled during this period. Data were collected for 97 variables, including the PAT and POE measurements of the vehicle axle weights and spacings, vehicle speed at the PAT test site, vehicle type, and independent factors such as the date, hour, and wind and weather conditions.

These field data were then used to compute an additional 51 variables, including tandem weights, differences between PAT and POE measurements, and error codes. A rigorous statistical analysis was made for these 148 variables to determine the accuracy and reliability of the PAT measurements and to identify significant relationships among the variables. For statistical control purposes, the POE data was assumed to be correct. (See Appendix B for scale certification.)

Appendix C contains a list of the variables, a descriptive review of the data, and the results of the multiple regression and correlation analyses. Although the mean average difference between the PAT and POE gross weights was small (4% of mean POE gross weight), the variations in measured weights for individual vehicles were much greater. In general, the PAT data was not sufficiently accurate to meet the ITD requirements, and the data analysis could not adequately explain the variations between PAT and POE measurements.

FOLLOW-UP STUDY: APRIL 1983

In an effort to improve reliability of the WIM data collection, a second study was made. PAT provided and installed four new weigh-plates and a new computer analog board. Data collection concentrated on the axle weights, the error codes, and a new variable referred to as the "pad location code." This code indicated the position of the vehicle crossing the PAT weigh-plates relative to the center of the pads. Data for the weather, road conditions, and axles spacings were not collected.

Sample data were collected for 209 trucks during the daylight hours of April 28 and 29, 1983. Appendix D presents the data, analyses, and results of this study. While the pad location code reduced some types of errors, statistically significant error rates were still found for some of the important variables.

CONCLUSIONS AND RECOMMENDATIONS

The WIM test equipment was removed from the roadway in 1984. Careful observations of the pavement and equipment during the dismantling provided useful information about proper installation and maintenance of the system. The field experience and analyses of the data from the two studies led to the following general conclusions.

1) Operating at highway speeds, the PAT Weigh-In-Motion system tested does not provide axle weights or axle spacings which are acceptable as direct substitutes for the POE static weight and spacing measurements.

2) Multiple regression models established relationships between vehicle weights and variables such as vehicle speed and pad location, but none of these relationships demonstrated the precision necessary to use the models for predictive purposes.

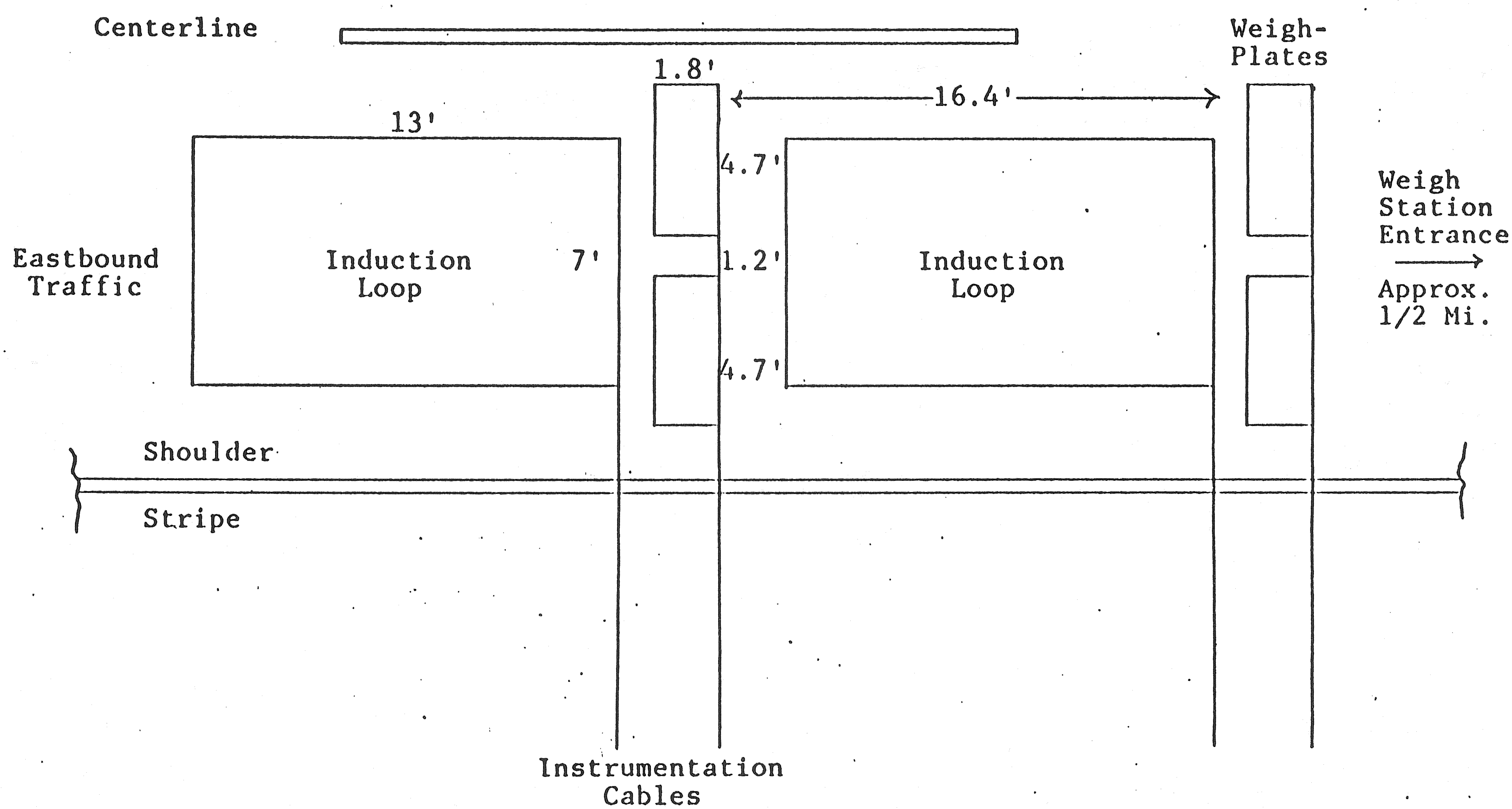
3) Despite large errors in the measured weights for individual vehicles, the small average error for the total sample indicated the PAT system will provide sufficiently accurate data for highway design loading.

4) The weather and road surface condition variables made no significant difference in the PAT performance for measuring gross vehicle weight.

5) Proper installation is critical to the performance and longevity of the WIM equipment. Of particular importance are a close fit between the pavement cut-out and the weigh-plate support frame and adequate drainage beneath the plates.

Though the Weigh-In-Motion equipment used in this project failed to demonstrate adequate reliability and accuracy at highway speeds, ITD remains optimistic about future applications of WIM technology. PAT has already applied the information and field experience gained from this research project to improve their products. ITD personnel also gained valuable experience with WIM technology and a better understanding of both the potential and the limitation of this equipment.

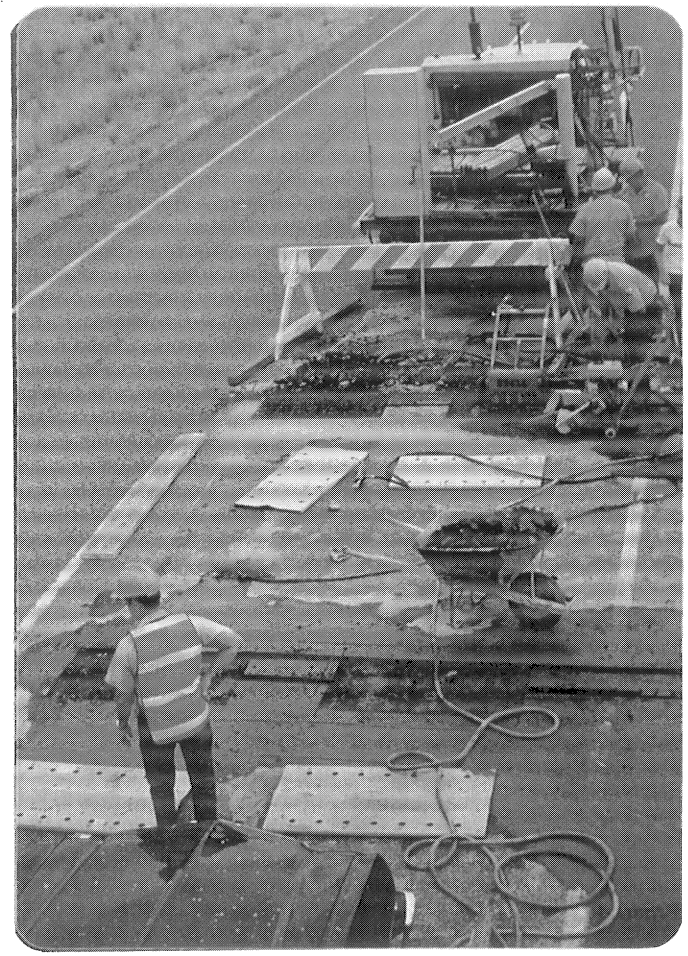
APPENDIX A



PAT WEIGHPLATES AND INDUCTION LOOPS

I84 NEAR BLISS WEIGH STATION

1



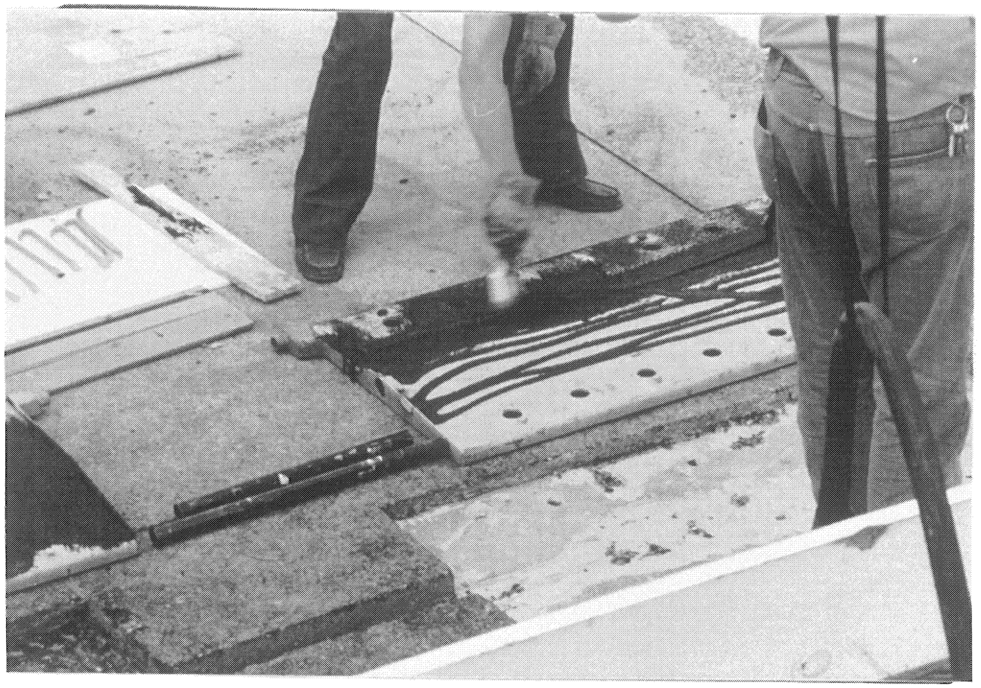
2

3

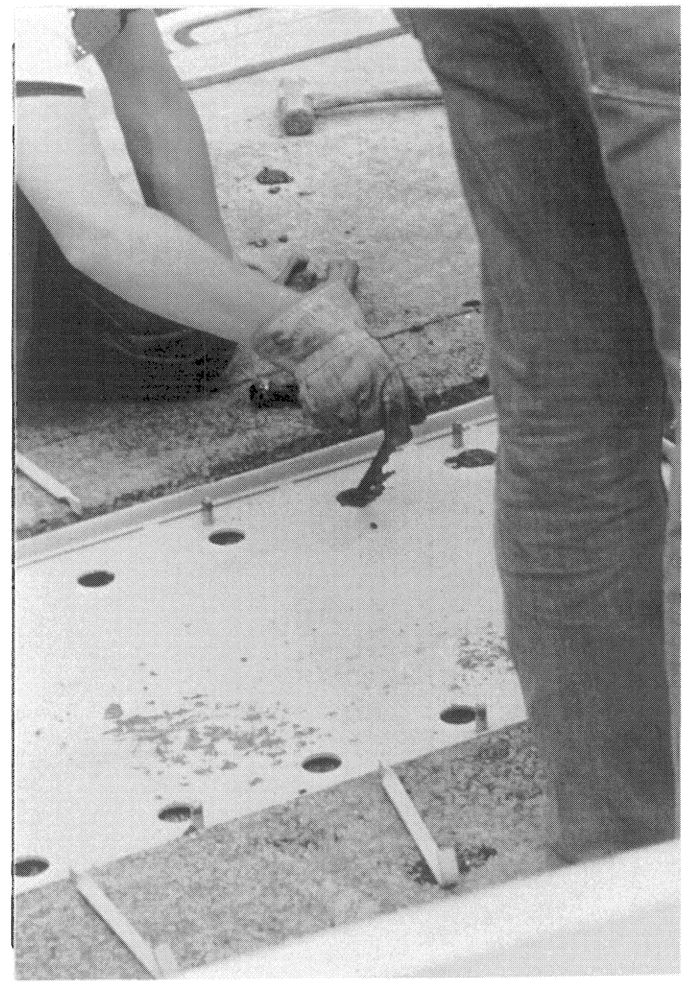
1. Cutting recess for weighplate mounting frame.

2. Finished pavement cuts.

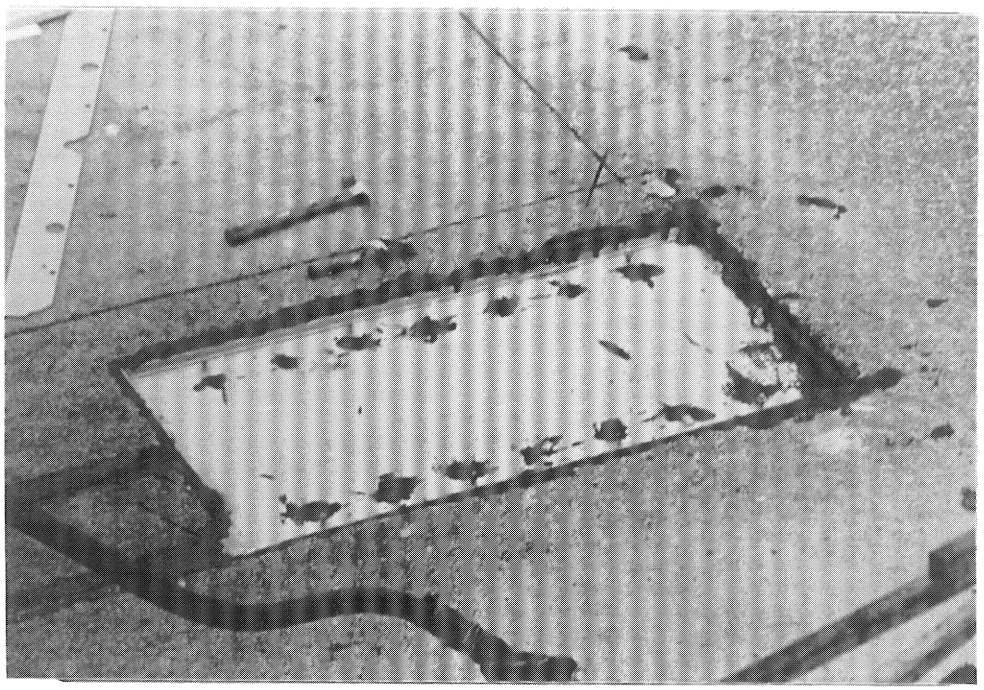
3. Mounting frames (Inverted) with anchor straps.



4



5

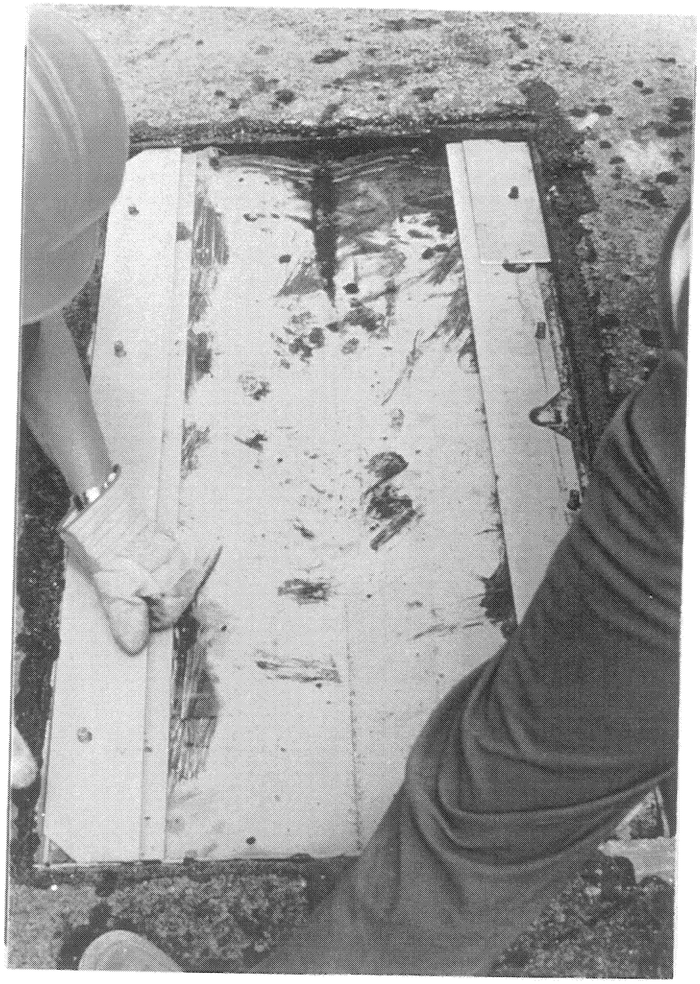


6

4. Coating bottom of mounting frame with mastic.

5. Inserting anchor straps into drilled hole filled with mastic.

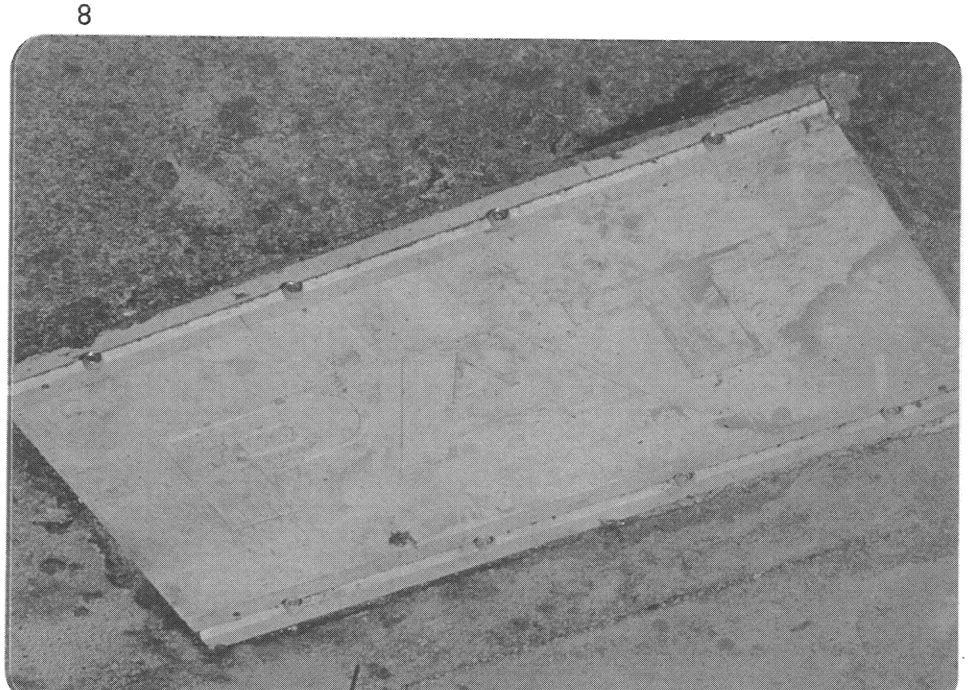
6. Mounting frame installed.



7

9

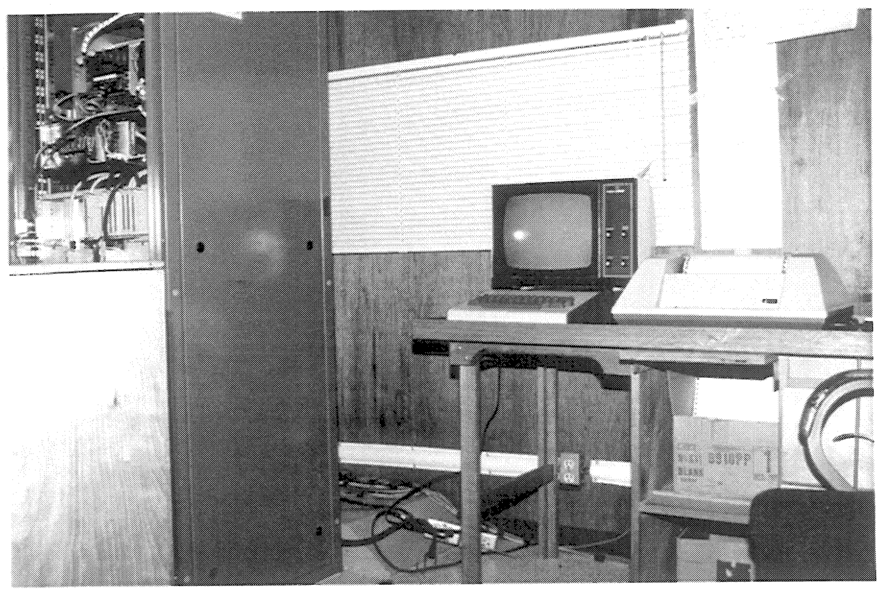
8



7. Installing weigh-plate support shims.

8. Weighplate installation completed.

9. Three axle calibration truck traveling across weighplates.



Printer

10

Operator's
Keyboard and
CRT Display

10. Interior of Instrumentation Van

APPENDIX B

CALIBRATION DATA

SPRING 1982

THREE AXLE CALIBRATION TRUCK

	20 mph		
	FEB	MAR	APR
Avg. Static Gross Wt.(1)	29308	30353	30357
Avg. PAT. Gross Wt.(2)	28730	30594	30356
PAT - Static/%	-578/-1.97	+241/+ .79	-1/ .00
Potentiometer Adjusted?	no	no	no

	40 mph		
	FEB	MAR	APR
Avg. Static Gross Wt.(1)	29308	30353	30357
Avg. PAT Gross Wt.(2)	28738	29752	30298
PAT - Static/%	-570/-1.95	-601/-1.98	-59/-.19
Potentiometer Adjusted?	yes	no	no
Avg. PAT Gross Wt. After Adj.(2)	29370	---	---
PAT - Static/% After Adj.	+62/+.02	---	---

CALIBRATION DATA
(Continued)

	60 mph		
	FEB	MAR	APR
Avg. Static Gross Wt.(1)	29308	30353	30357
Avg. PAT Gross Wt.(2)	27090	30584	31522
PAT - Static/%	-2218/-7.57	+231/+ .76	+1165/+3.84
Potentiometer Adjusted?	yes	no	yes
Avg. PAT Gross Wt. After Adj.(2)	28984	---	30450
PAT - Static/% After Adj.	-324/-1.11	---	+97/-0.31

(1) Avg. of at least 5 weighings at weigh station
(2) Avg. of 5 passes over PAT weighplates

DH-2216 2-72

SCALE APPROVAL LOG SHEET

(See Construction Manual Sec. 4-109.01)

Project X-1001

Scale Location Bliss Port of Entry East Bound Lane

☒ - Levelness check within 0.02' tolerance.

☑ - Installation approval Idaho T-26-68.

S - Settlement Check within 0.1' tolerance.

R - Rechecked for accuracy Idaho T-26-68.

C - Checked by comparing with batch weights, weights from commercial or other approved scales.

Approval Yes	No		Date	Signature	* Remarks
☑	☐	☐	7-13-77	Wm. E. Flanel	
☑	☐	☐	2-13-79	Sam S Larson	
☑	☐	R	12-18-79	Sam S. Larson	
☑	☐	R	5-13-80	Sam S Larson	
☑	☐	☐	5-11-81	Wm. E. Flanel	
☑	☐	☐	8-21-81	Wm. E. Flanel	
☑	☐	R	1/15/82	I L Mink	5/7/82 IVAN L. MINK
☐	☐	R	9/7/82	I L Mink	
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			

* Reference to Project Diary or A.V.O. when not approved.

Distribution: Resident Engineer/Chief

Customer Note: This is not an invoice. This is your acknowledgement that the services requested have been provided. You will be invoiced separately for all applicable charges.

WASHINGTON SCALE CO. 705 E. KARCHER RD. NAMPA, IDAHO 83651

(208) 467-3308
1-800-632-7426
Idaho Toll Free

DAILY WORK ORDER

DATE 12-2 19 81

CUSTOMER NAME STATE OF IDAHO SERVICE ORDER REPORT NUMBER 10595

ADDRESS ____ CUSTOMER P.O. NO. ____

TELEPHONE NO. ____ SCALE TYPE ____ SERIAL # ____

TYPE OF SERVICE: INSTALLATION ☐ FIELD REPAIR ☐ SHOP REPAIR ☐ F.R. ☐ MAINTENANCE AGREEMENT ☐

NAMPA ____ TWIN FALLS ____ POCATELLO ____ TECHNICIANS NAME [illegible signature]

WORK ACCOMPLISHED JACK up and GREASED SCALE on WEST Bound side. Also welded BACK FLEXER ARMS. WELDED BACK FLEXER ARMS on WEST Bound side Also. Also EAST Bound side NEED FLEXER arms welded.

REMARKS-DELAYS ____

QUAN.	PARTS DESCRIPTION

QUAN.	MATERIALS

☐ JOB INCOMPLETE

☑ JOB COMPLETE

[signature] MECHANIC SIGNATURE

Eugene M. Henzinger CUSTOMER SIGNATURE

TIME ARRIVED ON JOB 9:30

TIME DEPARTED FROM JOB 2:30

Printed in U.S.A.

CUSTOMER COPY

S/R No. 497

Scales UNLIMITED INC.
1030 West Finch
Nampa, Idaho 83651
Phone (208)465-0461

SERVICEMAN	
SCALE OWNER	S. HE A.E. BLISS [illegible]
SCALE LOCATION	BLISS EAST Bo. d

MAKE OF SCALE	TYPE	KIND OF BEAM OR DIAL
Firh	TRK	E.E.
MIN. GRAD.	SERIAL NUMBER	BALANCE INDICATOR

TEST DATE	LAST DATE TESTED	COND. OF APPROACHES	PLATFORM SIZE	SCALE CAPACITY	PIT DEPTH
1-7-82	12-4-81	G D	1 x 5 FT.	20,000	4 FT.

LIVESTOCK & VEHICLE SCALE TEST REPORT

AS FOUND				AFTER SERVICING & ADJ.			
S. R. ZERO	S. R. MAX.			S. R. ZERO	S. R. MAX		
TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)	TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)
POSITION (1)	POUNDS (2)			POSITION (1)	POUNDS (2)		
BALANCE	ZERO			BALANCE	ZERO		
CORNER							
10,000	10,000		ø				
10,000	10,000		ø				
10,000	10,000		ø				
10,000	10,000		ø				

REMARKS

-955 2-75

PLATFORM SCALE INSPECTION SHEET

PROJECT Bliss P.O.E.
SCALE LOCATION EBL
SCALE BRAND Fair Banks Morse
SMALLEST SCALE INDICATOR 20

CONTRACTOR ______
PIT NO. ______
SCALE SERIAL NO. G-799433
DATE 11/15/82

INSTALLATION CHECK:

1. ARE THE PLATFORM, KNIFE EDGES AND WORKING PARTS CLEAN AND DO THEY HAVE PROPER CLEARANCES TO PREVENT DISPLACEMENT, DRAGGING, OR RUBBING? YES____ NO____
2. IS THE SCALE CONSTRUCTED SO THAT NO SPRINGS CARRY PART OR ALL OF THE LOAD? YES____ NO____
3. ARE THE APPROACHES AND SCALE PLATFORM LEVEL TO ASSURE THAT ALL VEHICLES OR COMBINATION OF VEHICLES ARE AT THE SAME ELEVATION REGARDLESS OF WHICH IS BEING WEIGHED? YES____ NO____
4. HAS FORM DH-2216 BEEN POSTED TO SHOW THE RESULTS OF THE INITIAL LEVEL CHECK AND SUBSEQUENT CHECKS TO BE MADE DURING THE COURSE OF WEIGHING OPERATIONS? YES____ NO____
5. DOES THE INITIAL CHECK SHOW THE LEVELNESS TO BE WITHIN .02 FOOT AT THE CORNERS OF SCALE PLATFORM? YES____ NO____
6. ARE AT LEAST THE LAST 100 LB OF THE TOTAL LOAD INDICATED ON A GRADUATED SCALE? YES____ NO____
7. CHECK TYPE OF SCALE. ______ BEAM ______ SPRINGLESS DIAL digital
8. BALANCE SCALE AT ZERO LOAD.
9. CHECK (S.R.) SENSITIVITY RATIO AT ZERO LOAD.
   A. PLACE WEIGHTS ON SCALE DECK EQUAL TO TWO TIMES THE MINIMUM GRADUATION ON SCALE BEAM, IF NO SMALL WEIGHTS ARE AVAILABLE, MOVE THE COUNTER WEIGHT OR POISE TWO DIVISIONS ON THE SCALE BEAM. THIS SHOULD CAUSE END OF BEAM TO STAY AT THE TOP OR BOTTOM OF TRIG LOOP, DEPENDING ON WHICH METHOD IS USED. RECORD HOW MUCH WEIGHT IS NECESSARY TO HOLD THIS POSITION. ____________ LB.

WEIGH CHECK:

10. DRIVE LOADED TRUCK ON SCALE, MAKING SURE REAR WHEELS ARE OVER BEARING POINTS, AND WEIGH. REVERSE DIRECTION AND REWEIGH. DIFFERENCE OF EACH SECTION SHOULD BE LESS THAN 1.0% OF KNOWN TRUCK WEIGHT, IF SO, PROCEED WITH STEP 11.
11. TRUCK - WEIGHTS . . . .
12. INDICATED DIFFERENCE . . . .
13. KNOWN WEIGHT . . . .
14. ERROR (DIFFERENCE BETWEEN 12 AND 13) . . . .
15. PERCENT ERROR (NO. 14 ÷ NO. 13) . . . .

LEFT END	MIDDLE	RIGHT END
Load Applied	Read out.	
1000	1000	
2000	2000	
3000	3000	
4000	4000	
5000	5000	
6000	6000	
7000	7000	
8000	8000	
9000	9000	
10000	10000	
11000	11000	
12000	12000	
13000	13000	
14000	14000	

16. PERCENT ERROR________. IF THE PERCENT ERROR IS LESS THAN 1 PERCENT AND THE ANSWERS 1 THROUGH 6 INCLUSIVE ARE YES, A PROPERLY FILLED OUT INSPECTION STICKER SHOULD BE APPLIED TO THE SCALES.
17. DID YOU APPROVE THE SCALES? YES ✓ NO________

REMARKS: Knife edges and levelness was not inspected

L. Smink
INSPECTOR'S SIGNATURE

DISTRIBUTION: MATERIALS ENGINEER DISTRICT MATERIALS ENGINEER RESIDENT ENGINEER INSPECTOR

JAN 15 1982

*

10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
130.00
140.00

1.050.00 *

JAN 15 1982

-956 2-75

PLATFORM SCALE INSPECTION SHEET

OJECT *Port of Entry*
ALE LOCATION *EBL*
ALE BRAND *Fairbanks*
ALLEST SCALE INDICATOR *20 Lbs*

CONTRACTOR
PIT NO.
SCALE SERIAL NO. *G-799489*
DATE *5/7/82*

STALLATION CHECK:

, ARE THE PLATFORM, KNIFE EDGES AND WORKING PARTS CLEAN AND DO THEY HAVE PROPER CLEARANCES TO PREVENT DISPLACEMENT, DRAGGING, OR RUBBING? YES____ NO____

, IS THE SCALE CONSTRUCTED SO THAT NO SPRINGS CARRY PART OR ALL OF THE LOAD? YES____ NO____

, ARE THE APPROACHES AND SCALE PLATFORM LEVEL TO ASSURE THAT ALL VEHICLES OR COMBINATION OF VEHICLES ARE AT THE SAME ELEVATION REGARDLESS OF WHICH IS BEING WEIGHED? YES____ NO____

, HAS FORM DH-2216 BEEN POSTED TO SHOW THE RESULTS OF THE INITIAL LEVEL CHECK AND SUBSEQUENT CHECKS TO BE MADE DURING THE COURSE OF WEIGHING OPERATIONS? YES____ NO____

, DOES THE INITIAL CHECK SHOW THE LEVELNESS TO BE WITHIN .02 FOOT AT THE CORNERS OF SCALE PLATFORM? YES____ NO____

, ARE AT LEAST THE LAST 100 LB OF THE TOTAL LOAD INDICATED ON A GRADUATED SCALE? YES____ NO____

, CHECK TYPE OF SCALE. ______ BEAM ______ SPRINGLESS DIAL *Digital*

, BALANCE SCALE AT ZERO LOAD.

, CHECK (S.R.) SENSITIVITY RATIO AT ZERO LOAD.

A. PLACE WEIGHTS ON SCALE DECK EQUAL TO TWO TIMES THE MINIMUM GRADUATION ON SCALE BEAM, IF NO SMALL WEIGHTS ARE AVAILABLE, MOVE THE COUNTER WEIGHT OR POISE TWO DIVISIONS ON THE SCALE BEAM. THIS SHOULD CAUSE END OF BEAM TO STAY AT THE TOP OR BOTTOM OF TRIG LOOP, DEPENDING ON WHICH METHOD IS USED. RECORD HOW MUCH WEIGHT IS NECESSARY TO HOLD THIS POSITION. __________ LB.

IGH CHECK:

, DRIVE LOADED TRUCK ON SCALE, MAKING SURE REAR WHEELS ARE OVER BEARING POINTS, AND WEIGH. REVERSE DIRECTION AND REWEIGH. DIFFERENCE OF EACH SECTION SHOULD BE LESS THAN 1.0% OF KNOWN TRUCK WEIGHT, IF SO, PROCEED WITH STEP 11.

, TRUCK - WEIGHTS . . . .

, INDICATED DIFFERENCE . . . .

, KNOWN WEIGHT . . . .

, ERROR (DIFFERENCE BETWEEN 12 AND 13) . . . .

, PERCENT ERROR (NO. 14 ÷ NO. 13) . . . .

LEFT END	MIDDLE	RIGHT END
wt. Applied	*wt. Read*	
1000	*980*	
2000	*1980*	
3000	*3000*	
4000	*4000*	
5000	*5000*	
6000	*6000*	
7000	[illegible]	
8000	[illegible]	
9000	*9000*	
10000	*10020*	
11000	*11020*	
12000	*12020*	
13000	*13020*	
14000	*14020*	
15000	*15020*	*20 Lbs*

, PERCENT ERROR *0.13*. IF THE PERCENT ERROR [illegible] LESS THAN 1 PERCENT AND THE ANSWERS 1 THROUGH 6 INCLUSIVE ARE YES, A PROPERLY FILLED OUT INSPECTION STICKER SHOULD BE APPLIED TO THE SCALES.

, DID YOU APPROVE THE SCALES? YES *✓* NO____

MARKS: *Applied weights only.*

L L Mink
INSPECTOR'S SIGNATURE

STRIBUTION: MATERIALS SUPERVISOR DISTRICT MATERIALS ENGINEER RESIDENT ENGINEER INSPECTOR

6-1-82

East

S/R No. ______

WASHINGTON SCALE CO.

705 E. Karcher Rd.
Nampa, Idaho 83651
(208) 467-3308

Twin Falls &
Pocatello Res.
Mechanics
1-800-632-7426

SERVICEMAN [illegible]		
SCALE OWNER [illegible]		
SCALE LOCATION [illegible]		
MAKE OF SCALE [illegible]	TYPE [illegible]	KIND OF BEAM OR DIAL [illegible]
MIN. GRAD. 20 lb	SERIAL NUMBER	BALANCE INDICATOR [illegible]
PLATFORM SIZE 10 x 1[illegible] FT.	SCALE CAPACITY [illegible]	PIT DEPTH 4 FT.

TEST DATE	LAST DATE TESTED	COND. OF APPROACHES
[illegible]		[illegible]

LIVESTOCK & VEHICLE SCALE TEST REPORT

AS FOUND				AFTER SERVICING & ADJ.			
S. R. ZERO		S. R. MAX.		S. R. ZERO		S. R. MAX	
TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)	TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)
POSITION (1)	POUNDS (2)			POSITION (1)	POUNDS (2)		
BALANCE	ZERO			BALANCE	ZERO		
[illegible]	[illegible]						
[illegible]	[illegible]		[illegible]				
[illegible]	[illegible]		[illegible]				
[illegible]	[illegible]		[illegible]				
[illegible]	[illegible]		[illegible]				
	[illegible]		[illegible]				
	[illegible]		[illegible]				
	[illegible]		[illegible]				
	[illegible]		[illegible]				

REMARKS [illegible]

Customer Note: This is not an invoice. This is your acknowledgement that the services requested have been provided. You will be invoiced separately for all applicable charges.

WASHINGTON SCALE CO.

705 E. KARCHER RD.
NAMPA, IDAHO 83651

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DAILY WORK ORDER

DATE 6-2 19 82

CUSTOMER NAME State of Idaho

SERVICE ORDER REPORT NUMBER

ADDRESS Bliss

CUSTOMER P.O. NO. D-033090

TELEPHONE NO.

SCALE TYPE Axel SERIAL # 1275

TYPE OF SERVICE: INSTALLATION ☐ FIELD REPAIR ☒ SHOP REPAIR ☐ F.R. ☐ MAINTENANCE AGREEMENT ☐

NAMPA ____ TWIN FALLS X ____ POCATELLO ____ TECHNICIANS NAME ____

WORK ACCOMPLISHED cleaned & washed pit out welded Broken flexure made inspection & look fine, hooped weights & tested Axs. show on test Report. Both scale weighing within state tolerance.

REMARKS-DELAYS

QUAN.	PARTS DESCRIPTION

QUAN.	MATERIALS

☒ JOB INCOMPLETE

☐ JOB COMPLETE

MECHANIC SIGNATURE

CUSTOMER SIGNATURE

TIME ARRIVED ON JOB 10:30

TIME DEPARTED FROM JOB 5:00

Printed in U.S.A.

CUSTOMER COPY

6-1-82

East

S/R No.

WASHINGTON SCALE CO.

705 E. Kercher Rd.
Nampa, Idaho 83651
(208) 467-3308

Twin Falls & Pocatello Res. Mechanics
1-800-632-7426

SERVICEMAN [illegible]			
SCALE OWNER [illegible]			
SCALE LOCATION [illegible]			
MAKE OF SCALE [illegible]	TYPE [illegible]	KIND OF [illegible]	
MIN. GRAD. 20 [illegible]	SERIAL NUMBER	BALANCE INDICATOR [illegible]	
TEST DATE [illegible]	LAST DATE TESTED	COND. OF APPROACHES [illegible]	PLATFORM SIZE 10 x [illegible] FT.	SCALE CAPACITY [illegible]	PIT DEPTH 4 FT.

LIVESTOCK & VEHICLE SCALE TEST REPORT

AS FOUND — S. R. ZERO — S. R. MAX.

AFTER SERVICING & ADJ. — S. R. ZERO — S. R. MAX

AS FOUND TEST WEIGHTS POSITION (1)	POUNDS (2)	CORR. WGHTS. (3)	ERROR (4)	AFTER SERVICING TEST WEIGHTS POSITION (1)	POUNDS (2)	CORR. WGHTS. (3)	ERROR (4)
BALANCE	ZERO			BALANCE	ZERO		
[illegible]	[illegible]						
[illegible]	5000		0				
[illegible]	7500		0				
[illegible]	10000		0				
[illegible]	[illegible]		0				
[illegible]	20000		0				
[illegible]	30000		0				
[illegible]	[illegible]		0				

REMARKS [illegible]

-956 2-75

PLATFORM SCALE INSPECTION SHEET

OJECT Port of Entry
ALE LOCATION EBL
ALE BRAND Fairbanks
ALLEST SCALE INDICATOR 20 Lbs

CONTRACTOR ____
PIT NO. ____
SCALE SERIAL NO. G-799439
DATE 9/7/82

STALLATION CHECK:

. ARE THE PLATFORM, KNIFE EDGES AND WORKING PARTS CLEAN AND DO THEY HAVE PROPER CLEARANCES TO PREVENT DISPLACEMENT, DRAGGING, OR RUBBING? YES ____ NO ____

. IS THE SCALE CONSTRUCTED SO THAT NO SPRINGS CARRY PART OR ALL OF THE LOAD? YES ____ NO ____

. ARE THE APPROACHES AND SCALE PLATFORM LEVEL TO ASSURE THAT ALL VEHICLES OR COMBINATION OF VEHICLES ARE AT THE SAME ELEVATION REGARDLESS OF WHICH IS BEING WEIGHED? YES ____ NO ____

. HAS FORM DH-2216 BEEN POSTED TO SHOW THE RESULTS OF THE INITIAL LEVEL CHECK AND SUBSEQUENT CHECKS TO BE MADE DURING THE COURSE OF WEIGHING OPERATIONS? YES ____ NO ____

. DOES THE INITIAL CHECK SHOW THE LEVELNESS TO BE WITHIN .02 FOOT AT THE CORNERS OF SCALE PLATFORM? YES ____ NO ____

. ARE AT LEAST THE LAST 100 LB OF THE TOTAL LOAD INDICATED ON A GRADUATED SCALE? YES ____ NO ____

. CHECK TYPE OF SCALE. ____ BEAM ____ SPRINGLESS DIAL Digital

. BALANCE SCALE AT ZERO LOAD.

. CHECK (S.R.) SENSITIVITY RATIO AT ZERO LOAD.

A. PLACE WEIGHTS ON SCALE DECK EQUAL TO TWO TIMES THE MINIMUM GRADUATION ON SCALE BEAM, IF NO SMALL WEIGHTS ARE AVAILABLE, MOVE THE COUNTER WEIGHT OR POISE TWO DIVISIONS ON THE SCALE BEAM. THIS SHOULD CAUSE END OF BEAM TO STAY AT THE TOP OR BOTTOM OF TRIG LOOP, DEPENDING ON WHICH METHOD IS USED. RECORD HOW MUCH WEIGHT IS NECESSARY TO HOLD THIS POSITION. ____ LB.

IGH CHECK:

. DRIVE LOADED TRUCK ON SCALE, MAKING SURE REAR WHEELS ARE OVER BEARING POINTS, AND WEIGH. REVERSE DIRECTION AND REWEIGH. DIFFERENCE OF EACH SECTION SHOULD BE LESS THAN 1.0% OF KNOWN TRUCK WEIGHT, IF SO, PROCEED WITH STEP 11.

. TRUCK - WEIGHTS . . . .

. INDICATED DIFFERENCE . . . .

. KNOWN WEIGHT . . . .

. ERROR (DIFFERENCE BETWEEN 12 AND 13) . . . .

. PERCENT ERROR (NO. 14 + NO. 13) . . . .

LEFT END Wt Applied	MIDDLE Wt Read	RIGHT END
1000	1000	
2000	2000	
3000	3000	
4000	4000	
5000	5000	
6000	6000	
7000	7000	
8000	8000	
9000	9000	
10000	10000	
11000	11000	
12000	12000	
13000	13000	
14000	14000	
15000	15000	

. PERCENT ERROR 0 . IF THE PERCENT ERROR IS LESS THAN 1 PERCENT AND THE ANSWERS 1 THROUGH 6 INCLUSIVE ARE YES, A PROPERLY FILLED OUT INSPECTION STICKER SHOULD BE APPLIED TO THE SCALES.

. DID YOU APPROVE THE SCALES? YES ✓ NO ____

MARKS: Applied wts only

INSPECTOR'S SIGNATURE

ISTRIBUTION: MATERIALS SUPERVISOR DISTRICT MATERIALS ENGINEER RESIDENT ENGINEER INSPECTOR

S/R No. 433

Scales UNLIMITED INC.

1030 West Finch
Nampa, Idaho 83651
Phone (208)465-0461

SERVICEMAN: Bob Schlund

SCALE OWNER: STATE OF IDAHO

SCALE LOCATION: 55

MAKE OF SCALE	TYPE	KIND OF BEAM OR DIAL
[illegible]	TNK	[illegible]
MIN. GRAD.	SERIAL NUMBER	BALANCE INDICATOR
[illegible]	[illegible]	

TEST DATE	LAST DATE TESTED	COND. OF APPROACHES	PLATFORM SIZE	SCALE CAPACITY	PIT DEPTH
12-9-82	[illegible]		x 12 FT.	[illegible]	7 FT.

LIVESTOCK & VEHICLE SCALE TEST REPORT

AS FOUND				AFTER SERVICING & ADJ.			
S. R. ZERO		S. R. MAX.		S. R. ZERO		S. R. MAX	
TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)	TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)
POSITION (1)	POUNDS (2)			POSITION (1)	POUNDS (2)		
BALANCE	ZERO			BALANCE	ZERO		
Corners [illegible] 1000							
				[illegible]	7,000		0
15,000	1500		0	[illegible]	11,000		0
15,000	1500		0	[illegible]	9,000		0
15,000	1500		0	[illegible]	9,000		0
15,000	1500		0				
				[illegible]			
				[illegible]	10,000		0
3000	3000		0	[illegible]	10,000		0
3000	3000		0	[illegible]	8,000		
3000	3000		0				
3000	3000		0				
6000	6,000		0				
6000	6,000		0				
6000			0				
6000	6,000		0				

REMARKS

S/R No. 433

Scales UNLIMITED INC.

1030 West Finch
Nampa, Idaho 83651
Phone (208)465-0461

SERVICEMAN		
BOB Schlund		
SCALE OWNER		
STATE OF IDAHO		
SCALE LOCATION		
RL 55		
MAKE OF SCALE	TYPE	KIND OF BEAM OR DIAL
F/M	TRK	93 C 1/2 H
MIN. GRAD.	SERIAL NUMBER	BALANCE INDICATOR
5LB	C774131	
PLATFORM SIZE	SCALE CAPACITY	PIT DEPTH
C x 12 FT.	50,000	4 FT.

TEST DATE	LAST DATE TESTED	COND. OF APPROACHES
12-9-82		1

LIVESTOCK & VEHICLE SCALE TEST REPORT

AS FOUND				AFTER SERVICING & ADJ.			
S. R. ZERO	S. R. MAX.			S. R. ZERO	S. R. MAX		
TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)	TEST WEIGHTS		CORR. WGHTS. (3)	ERROR (4)
POSITION (1)	POUNDS (2)			POSITION (1)	POUNDS (2)		
BALANCE	ZERO			BALANCE	ZERO		
CORRALS Buildup							
				[illegible]	7,000		0
15,000	1500		0	[illegible]	11,000		0
15,000	1500		0	[illegible]	9,000		0
15,000	1500		0	[illegible]	9,000		0
15,000	1500		0				
				[illegible]			
3000	3000		0	[illegible]	10,000		0
3000	3000		0	[illegible]	10,000		0
3000	3000		0	[illegible]	10,000		
3000	3000		0				
6000	6,000		0				
6000	6,000		0				
6000			0				
6000	6,000		0				

REMARKS

IDAHO TRANSPORTATION DEPARTMENT

PAT RESEARCH PROJECT 95

PAT WIM EQUIPMENT AND INSTALLATION COST

PAT WIM Equipment		$12,000
Labor	$6,300	
Travel & Subsistance	1,500	
Materials	600	
Equipment Ditchwitch, Air Compressor, Tar Pot, chippers, Tampers, and Concrete Saw	700	
Electrical Installation Cost	800	9,900
Total Installation & PAT Equipment		$21,900

Total cost of PAT Research Project 95 through September 30, 1982, for data collection and Analysis is $82,000.

APPENDIX C

APPENDIX C

SIX-MONTH STUDY

Introduction

These analyses are based on vehicle samples from the six-month period, February 1982 through July 1982. A total of 1218 vehicles were sampled during this period.

A descriptive review of the data for each variable is presented. In addition, the results of regression and correlation analyses are discussed. Finally, due to disappointing preliminary results based on the first three month's data, this report also presents an analysis aimed at isolating the causes and/or factors associated with measurement differences between PAT measurements and corresponding POE measurements.

Descriptive Analysis

The combined six-month sample consisted of 1218 vehicles. Table 1 shows the breakdown of the sample by month. During the sampling period each month, vehicles were measured throughout a 24-hour period. The frequency distribution of vehicles by hour of day sampled is provided in Table 2.

Table 1

Vehicles Sampled by Month

Month	Number	Percent
February	191	15.7
March	211	17.3
April	211	17.3
May	222	18.2
June	194	15.9
July	189	15.6
	1218	100.0

Table 2

Frequency of Vehicles by Hour of Day

AM			PM		
Hour	Frequency	Percent	Hour	Frequency	Percent
0000-0100	46	3.8	1200-1300	61	5.0
0100-0200	50	4.1	1300-1400	56	4.6
0200-0300	48	3.9	1400-1500	60	4.9
0300-0400	47	3.9	1500-1600	47	3.9
0400-0500	47	3.9	1600-1700	36	3.0
0500-0600	51	4.2	1700-1800	60	4.9
0600-0700	49	4.0	1800-1900	59	4.9
0700-0800	39	3.2	1900-2000	39	3.2
0800-0900	50	4.1	2000-2100	48	3.9
0900-1000	61	5.0	2100-2200	49	4.0
1000-1100	61	5.0	2200-2300	46	3.8
1100-1200	65	5.3	2300-2400	42	3.5
	614	50.4		603	49.6

*Note: One case was coded incorrectly.

For each vehicle in the sample, data were measured for up to 97 variables. From these 97 variables, an additional 51 variables were computed. Table 3 shows the 148 variables making up the data base. The variables labeled VAR01 through VAR95 and VAR146 and VAR147 were recorded during the sampling. Variables labeled VAR96 through VAR145 and VAR148 are computed variables.

Most of the labels shown in Table 3 are self-explanatory. However, several variables need further explanation. For instance, VAR72 through VAR95 refer to tandem axle weights. In collecting the data, any axle which is part of a tandem combination has a tandem weight measurement for the appropriate tandem combination and a zero (missing value) weight assigned to the individual axle. VAR96 through VAR135 are computed variables which measure differences between POE weight and spacing measurements and corresponding PAT weight and spacing measurements. Computed variables VAR136 through VAR145 are referred to as dummy variables. They are coded 1 if the appropriate response is "yes" and 0 if "no". The manipulation error codes are VAR146 and are explained in Table 8. If one of the four weigh pads failed to record all the axle weights, this generated a pad error code, VAR147, as shown in Table 9.

Table 4 shows the distribution of vehicles by vehicle type. The predominant type is the 3S2, with 972 occurrences or nearly 80 percent of the vehicles sampled.

TABLE 3

DATA BASE VARIABLES

VAR01,MONTH/
VAR02,DAY/
VAR03,YEAR/
VAR04,HOUR/
VAR05,VEHICLE TYPE/
VAR06,SERIAL NUMBER/
VAR07,POE A WEIGHT/
VAR08,POE B WEIGHT/
VAR09,POE C WEIGHT/
VAR10,POE D WEIGHT/
VAR11,POE E WEIGHT/
VAR12,POE F WEIGHT/
VAR13,POE G WEIGHT/
VAR15,POE AB SPACING/
VAR16,POE BC SPACING/
VAR17,POE CD SPACING/
VAR18,POE DE SPACING/
VAR19,POE EF SPACING/
VAR20,POE FG SPACING/
VAR21,POE TOTAL SPACING/
VAR22,POE BUMPER TO BUMPER/
VAR23,POE H WEIGHT/
VAR24,POE I WEIGHT/
VAR25,POE J WEIGHT/
VAR26,POE K WEIGHT/
VAR27,POE L WEIGHT/
VAR28,POE M WEIGHT/
VAR29,POE GH SPACING/
VAR30,POE HI SPACING/
VAR31,POE IJ SPACING/
VAR32,POE JK SPACING/
VAR33,POE KL SPACING/
VAR34,POE LM SPACING/
VAR35,PAT A WEIGHT/
VAR36,PAT B WEIGHT/
VAR37,PAT C WEIGHT/
VAR38,PAT D WEIGHT/
VAR39,PAT E WEIGHT/
VAR40,PAT F WEIGHT/
VAR41,PAT G WEIGHT/
VAR42,PAT GROSS WEIGHT/
VAR43,PAT AB SPACING/
VAR44,PAT BC SPACING/
VAR45,PAT CD SPACING/
VAR46,PAT DE SPACING/
VAR47,PAT EF SPACING/
VAR48,PAT FG SPACING/
VAR49,PAT TOTAL SPACING/

TABLE 3 CONTINUED

VAR50,PAT BUMPER TO BUMPER/
VAR51,PAT H WEIGHT/
VAR52,PAT I WEIGHT/
VAR53,PAT J WEIGHT/
VAR54,PAT K WEIGHT/
VAR55,PAT L WEIGHT/
VAR56,PAT M WEIGHT/
VAR57,PAT GH SPACING/
VAR58,PAT HI SPACING/
VAR59,PAT IJ SPACING/
VAR60,PAT JK SPACING/
VAR61,PAT KL SPACING/
VAR62,PAT LM SPACING/
VAR63,TEMPERATURE/
VAR64,WIND SPEED/
VAR65,WIND DIRECTION/
VAR66,SURFACE CONDITION/
VAR67,SAND/
VAR68,WEATHER/
VAR69,HUMIDITY/
VAR70,BAR.PRESSURE/
VAR71,VEHICLE SPEED/
VAR72,POE TAND AB WEIGHT/
VAR73,POE TAND BC WEIGHT/
VAR74,POE TAND CD WEIGHT/
VAR75,POE TAND DE WEIGHT/
VAR76,POE TAND EF WEIGHT/
VAR77,POE TAND FG WEIGHT/
VAR78,POE TAND GH WEIGHT/
VAR79,POE TAND HI WEIGHT/
VAR80,POE TAND IJ WEIGHT/
VAR81,POE TAND JK WEIGHT/
VAR82,POE TAND KL WEIGHT/
VAR83,POE TAND LM WEIGHT/
VAR84,PAT TAND AB WEIGHT/
VAR85,PAT TAND BC WEIGHT/
VAR86,PAT TAND CD WEIGHT/
VAR87,PAT TAND DE WEIGHT/
VAR88,PAT TAND EF WEIGHT/
VAR89,PAT TAND FG WEIGHT/
VAR90,PAT TAND GH WEIGHT/
VAR91,PAT TAND HI WEIGHT/
VAR92,PAT TAND IJ WEIGHT/
VAR93,PAT TAND JK WEIGHT/
VAR94,PAT TAND KL WEIGHT/
VAR95,PAT TAND LM WEIGHT/
VAR96,POE A - PAT A/
VAR97,POE B - PAT B/
VAR98,POE C - PAT C/
VAR99,POE D - PAT D/
VAR100,POE E - PAT E/

TABLE 3 CONTINUED

VAR101,POE F - PAT F/
VAR102,POE G - PAT G/
VAR103,POE H - PAT H/
VAR104,POE I - PAT I/
VAR105,POE J - PAT J/
VAR106,POE L - PAT L/
VAR107,POE M - PAT M/
VAR109,POE GROSS - PAT GROSS/
VAR110,SPACING DIFF AB/
VAR111,SPACING DIFF BC/
VAR112,SPACING DIFF CD/
VAR113,SPACING DIFF DE/
VAR114,SPACING DIFF EF/
VAR115,SPACING DIFF FG/
VAR116,TOTAL SPACING DIFF/
VAR117,TOTAL BUMPER DIFFERENCE/
VAR118,SPACING DIFF GH/
VAR119,SPACING DIFF HI/
VAR120,SPACING DIFF IJ/
VAR121,SPACING DIFF JK/
VAR122,SPACING DIFF KL/
VAR123,SPACING DIFF LM/
VAR124,TAND DIFF AB/
VAR125,TAND DIFF BC/
VAR126,TAND DIFF CD/
VAR127,TAND DIFF DE/
VAR128,TAND DIFF EF/
VAR129,TAND DIFF FG/
VAR130,TAND DIFF GH/
VAR131,TAND DIFF HI/
VAR132,TAND DIFF IJ/
VAR133,TAND DIFF JK/
VAR134,TAND DIFF KL/
VAR135,TAND DIFF LM/
VAR136,DRY DUMMY/
VAR137,WET DUMMY/
VAR138,ICY SPOTS DUMMY/
VAR139,ICY DUMMY/
VAR140,BROKEN SNOW DUMMY/
VAR141,CLEAR DUMMY/
VAR142,CLOUDY DUMMY/
VAR143,RAIN DUMMY/
VAR144,FOG DUMMY/
VAR145,SNOWING DUMMY/
VAR146,MANIPULATION ERROR CODES/
VAR147,PAD ERROR CODES/
VAR148,GROSS WEIGHT DIFFERENCE-PERCENTAGE/

Table 4

Frequency By Vehicle Type

Vehicle Type	Code	Frequency	Percent
2D	21.	9	0.7
2-1	30.	13	1.1
3-A	31.	14	1.1
2-2	40.	1	0.1
2S-2	41.	30	2.5
3S-1	42.	7	0.6
4A	45.	1	0.1
2S1-2	50.	52	4.3
3-2	52.	36	3.0
3S-2	53.	972	79.8
3S1-2	62.	15	1.2
3-3	63.	3	0.2
	69.	7	0.6
2S1-2-2	70.	27	2.2
3S2-2	74.	15	1.2
3S1-2-2	82.	6	0.5
3S2-3	85.	4	0.3
Unknown	99.	6	0.5
	Total	1218	100.0

Table 5

Frequency of Vehicles By Wind Direction

Direction	Code	Frequency	Percent
North	1.	10	0.8
Northeast	2.	113	9.3
East	3.	145	11.9
Southeast	4.	155	12.7
South	5.	41	3.4
Southwest	6.	183	15.0
West	7.	150	12.3
Northwest	8.	15	1.2
Calm	0.	406	33.3
	Total	1218	100.0

Table 6

Frequency of Vehicles By Surface Condition

Condition	Code	Frequency	Percent
Dry	1.	1124	92.3
Wet	2.	91	7.5
Missing	0.	3	0.2
	Total	1218	100.0

Table 7

Frequency of Vehicle By Weather Category

Category	Code	Frequency	Percent
Clear	1.	1059	86.9
Cloudy	2.	113	9.3
Rain	3.	42	3.4
Missing	0.	4	0.3
	Total	1218	100.0

The data were collected over a wide range of weather and road conditions. Tables 5-7 show the frequency distribution of vehicles observed at the various levels of variables VAR65, VAR66, and VAR67. The predominant surface and weather condition was dry and clear.

The way a vehicle crosses the PAT scales is thought to be critical to the performance of the PAT system in terms of weighing and measuring the vehicles. The PAT scale attempts to analyze the vehicle crossing by recording levels of error for two error classes: manipulation error and pad error. Tables 8 and 9 show the distribution of vehicles by error code for these two error classes. The most common manipulation error involves imbalance, while only Pad 4 showed a pad error with any significant frequency (15.6 percent). Only 5.1 percent of the vehicles sampled measure zero manipulation error, while 80.1 percent measured no pad error.

Table 8

Frequency of Vehicles By Manipulation Error Code

Code Description	Code	Frequency	Percent
Imbalance 10% "No error"	0.	62	5.1
Imbalance 10-19%	1.	313	25.7
Imbalance 20-29%	2.	307	25.2
Imbalance >29%	3.	506	41.5
Speed Var >10%	4.	1	0.1
Imbalance 20-29% and Speed Var >10%	6.	2	0.2
Imbalance >29% and Speed Var >10%	7.	4	0.3
Scattering >50%	8.	5	0.4
Imbalance 10-19% and Scattering >50%	9.	1	0.1
Imbalance 20-29% and Scattering >50%	10.	2	0.2
Imbalance >29% and Speed Var >10% and Scattering > 50%	11.	1	0.1
Missing	99.	14	1.1
	Total	1218	100.0

Manipulation Error Definitions

"Imbalance" is a measure of the difference in weights measured by the left and right side weigh pads for the same axle.

"Speed Variance" is a measure of the difference in vehicle speed calculated for different axles on the same vehicle.

"Scattering" is a cumulative measure of the imbalance among certain combinations of weigh pads.

Table 9

Vehicle Frequency By Pad Error Code

Pad Error Description	Code	Frequency	Percent
No error	0.	976	80.1
Pad 4	1.	190	15.6
Pad 3	2.	25	2.1
Pad 2	4.	3	0.2
Pads 2 and 4	5.	9	0.7
Pads 2 and 3	6.	2	0.2
Pad 1	8.	9	0.7
Pads 1 and 4	9.	2	0.2
Pads 1 and 3	10.	2	0.2
	Total	1218	100.0

Descriptive measures for the ratio level variables are summarized in Table 10. Of particular importance to this study are the descriptive measures for the difference variables which reflect the difference between POE weights or spacings and PAT weights or spacings. In all cases, the difference is computed by subtracting the PAT value from the POE value. Thus, a positive difference means the POE value exceeded the PAT value.

Table 11 presents the results of the paired difference tests for determining whether the weight and spacing differences are statistically different from zero. The paired difference test is employed when we wish to test the following null and alternative hypotheses:

null H_o: $M_d = 0$

alt. H_a: $M_d \neq 0$

Where:

M_d = average paired difference

The paired difference test is appropriate in this case (as opposed to the two sample T-test) since the samples (POE measurements and PAT measurements) are not independent. That is, a weight measurement on axle A at the PAT scale is compared to a weight measurement on axle A at the POE for <u>the same</u> truck.

The appropriate test statistic is:

$$t = \frac{\frac{\bar{d}-Md}{S_d}}{\sqrt{n}}$$

Where:

Md = hypothesized average difference = 0

$\bar{d}$ = mean difference

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

d = paired deviation of the differences

S_d = standard deviation of the differences

$$S_d = \sqrt{\frac{\sum_{i=1}^{n} (d_i - \bar{d}^2)}{n-1}}$$

n = sample size (valid cases)

Table 11 shows that, in all but two cases, it must be concluded that a statistically significant paired difference exists between POE measurements and PAT measurements. Further, of those instances where a significant difference exists, in all but two instances, the sign of the test statistic is positive, meaning the PAT system tends to under-weigh and under-measure the POE values. The exceptions are axle spacing between axles D and E and total bumper to bumper spacing.

TABLE 10

DESCRIPTIVE MEASURES

VARIABLE	DESCRIPTION	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	RANGE	VALID CASES
07	POE Axle "A" Wgt	10,177	1,171	34	5,580	15,820	10,240	1217
08	POE Axle "B" Wgt	14,386	3,429	296	4,440	21,500	17,060	134
09	POE Axle "C" Wgt	11,959	3,788	391	4,800	19,340	14,540	94
10	POE Axle "D" Wgt	11,780	4,577	381	3,020	21,150	18,130	144
11	POE Axle "E" Wgt	11,070	4,635	396	3,280	19,950	16,670	137
12	POE Axle "F" Wgt	9,389	4,313	523	2,780	19,960	17,180	68
13	POE Axle "G" Wgt	8,500	4,022	569	3,100	19,820	16,720	50
23	POE Axle "H" Wgt	9,000	1,999	816	6,160	12,200	6,040	6
14	POE Gross Weight	62,343	18,807	539	15,180	107,380	92,200	1218
72	POE Tandem "AB" Wgt	21,340	-0-	-0-	21,340	21,340	-0-	1
73	POE Tandem "BC" Wgt	27,350	7,800	243	9,020	41,820	32,800	1083
74	POE Tandem "CD" Wgt	19,379	7,325	1,295	7,760	44,820	37,060	32
75	POE Tandem "DE" Wgt	25,496	9,486	299	5,900	48,320	42,420	1006
76	POE Tandem "EF" Wgt	16,690	10,176	5,088	7,560	28,720	21,160	4
77	POE Tandem "FG" Wgt	10,680	-0-	-0-	10,680	10,680	-0-	1
78	POE Tandem "GH" Wgt	16,560	4,478	2,239	12,380	22,160	9,780	4
79	POE Tandem "HI" Wgt	8,560	-0-	-0-	8,560	8,560	-0-	1
15	POE "AB" Spacing	14.0	2.9	0.1	4.4	23.2	18.8	1218
16	POE "BC" Spacing	6.2	5.6	0.2	4.0	33.5	29.5	1209
17	POE "CD" Spacing	26.6	7.0	0.2	4.0	40.8	36.8	1183
18	POE "DE" Spacing	5.9	5.1	0.1	3.6	35.0	31.4	1147
19	POE "EF" Spacing	12.0	5.6	0.6	4.0	23.8	19.8	82
20	POE "FG" Spacing	17.7	4.7	0.6	4.0	21.2	17.2	56
29	POE "GH" Spacing	14.8	8.7	2.6	4.0	27.0	23.0	11
30	POE "HI" Spacing	4.0	-0-	-0-	4.0	4.0	-0-	1
21	POE Total Spacing	53.3	9.6	0.3	14.9	96.7	81.8	1218
22	POE Bumper-to-Bumper	58.9	9.1	0.3	24.0	105.2	81.2	1217

TABLE 10

DESCRIPTIVE MEASURES (Cont'd)

VARIABLE	DESCRIPTION	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	RANGE	VALID CASES
35	PAT Axle "A" Wgt	9,687	1,528	44	2,260	15,550	13,290	1217
36	PAT Axle "B" Wgt	13,782	3,826	332	4,520	20,900	16,380	133
37	PAT Axle "C" Wgt	11,267	4,132	426	2,570	19,470	16,900	94
38	PAT Axle "D" Wgt	11,463	5,034	414	2,210	22,270	20,060	148
39	PAT Axle "E" Wgt	10,550	5,001	427	2,240	21,230	18,990	137
40	PAT Axle "F" Wgt	8,776	4,195	513	3,340	18,920	15,580	67
41	PAT Axle "G" Wgt	7,657	3,647	521	2,570	17,950	15,380	49
51	PAT Axle "H" Wgt	8,527	1,640	670	6,740	10,970	4,230	6
42	PAT Gross Weight	59,856	20,338	583	10,770	108,950	98,180	1218
84	PAT Tandem "AB" Wgt	4,190	-0-	-0-	4,190	4,190	-0-	1
85	PAT Tandem "BC" Wgt	26,475	9,084	276	3,460	42,280	38,820	1084
86	PAT Tandem "CD" Wgt	17,089	6,173	1,109	7,300	29,680	22,380	31
87	PAT Tandem "DE" Wgt	24,521	9,951	314	3,450	49,100	45,650	1002
88	PAT Tandem "EF" Wgt	16,623	11,202	5,601	7,040	28,860	21,820	4
89	PAT Tandem "FG" Wgt	8,685	361	255	8,430	8,940	510	2
90	PAT Tandem "GH" Wgt	16,040	3,167	1,416	12,510	19,920	7,410	5
91	PAT Tandem "HI" Wgt	9,020	-0-	-0-	9,020	9,020	-0-	1
43	PAT "AB" Spacing	13.6	2.9	0.1	3.9	28.8	24.9	1218
44	PAT "BC" Spacing	6.1	5.5	0.2	3.7	33.3	29.6	1209
45	PAT "CD" Spacing	26.5	6.9	0.2	3.6	41.0	37.4	1182
46	PAT "DE" Spacing	6.0	5.0	0.1	3.2	35.0	31.8	1143
47	PAT "EF" Spacing	11.8	5.5	0.6	3.6	23.8	20.2	81
48	PAT "FG" Spacing	17.7	4.7	0.6	4.5	21.2	16.7	56
57	PAT "GH" Spacing	13.9	8.8	2.5	3.8	26.9	23.1	12
58	PAT "HI" Spacing	4.2	-0-	-0-	4.2	4.2	-0-	1
49	PAT Total Spacing	52.8	9.5	0.3	14.8	97.2	82.4	1218
50	PAT Bumper-to-Bumper	59.6	9.3	0.3	24.5	103.0	78.5	1218

TABLE 10

DESCRIPTIVE MEASURES (Cont'd)

VARIABLE	DESCRIPTION	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	RANGE	VALID CASES
96	Diff POE "A" - PAT "A"	490	1,138	33	-1,730	7,460	9,190	1217
97	Diff POE "B" - PAT "B"	593	2,172	188	-4,740	8,600	13,340	133
98	Diff POE "C" - PAT "C"	692	1,853	191	-5,080	9,900	14,980	94
99	Diff POE "D" - PAT "D"	381	1,528	127	-2,490	8,160	10,650	144
100	Diff POE "E" - PAT "E"	621	1,605	138	-5,410	9,670	15,080	136
101	Diff POE "F" - PAT "F"	584	1,138	140	-1,560	6,750	8,310	66
102	Diff POE "G" - PAT "G"	613	1,643	235	-4,250	7,420	11,670	49
103	Diff POE "H" - PAT "H"	473	1,058	432	-1,050	1,460	2,510	6
109	Diff Gross Weight	2,486	8,624	247	-26,480	50,860	77,340	1218
124	Diff Tandem "AB"	17,150	-0-	-0-	17,150	17,150	-0-	1
125	Diff Tandem "BC"	860	4,126	125	-14,300	22,570	36,870	1083
126	Diff Tandem "CD"	2,124	6,805	1,222	-3,520	32,490	36,010	31
127	Diff Tandem "DE"	981	3,849	122	-11,900	22,780	34,680	1002
128	Diff Tandem "EF"	68	1,582	791	-1,900	1,940	3,840	4
129	Diff Tandem "FG"	2,250	-0-	-0-	2,250	2,250	-0-	1
130	Diff Tandem "GH"	1490	2,277	1,139	-650	4,710	5,360	4
131	Diff Tandem "HI"	-460	-0-	-0-	-460	-460	-0-	1
110	Diff "AB" Spacing	0.3	1.0	0.0	-17.2	8.6	25.8	1218
111	Diff "BC" Spacing	0.1	0.7	0.0	-3.2	21.5	24.7	1209
112	Diff "CD" Spacing	0.2	0.6	0.0	-6.3	5.6	11.9	1182
113	Diff "DE" Spacing	0.1	0.4	0.0	-4.0	1.3	5.3	1143
114	Diff "EF" Spacing	0.1	0.4	0.0	-1.1	0.8	1.9	81
115	Diff "FG" Spacing	0.1	0.6	0.1	-2.9	1.5	4.4	56
118	Diff "GH" Spacing	0.1	0.3	0.1	-0.5	0.6	1.1	11
119	Diff "HI" Spacing	-0.2	0.0	0.0	-0.2	-0.2	0.0	1
116	Diff Total Spacing	0.6	1.4	0.0	-18.1	20.5	38.6	1218
117	Diff Bumper-to-Bumper	-0.7	1.7	0.1	-14.5	9.2	23.7	1217

Table 11

Paired Difference Tests

Variables	Compute t Statistics	Sample Size	Significant (alph=.05)
VAR96	15.02	1217	*
VAR97	3.15	133	*
VAR98	3.62	94	*
VAR99	2.99	144	*
VAR100	4.50	136	*
VAR101	4.17	66	*
VAR102	2.61	49	*
VAR109	10.06	1218	*
VAR110	10.80	1218	*
VAR111	3.45	1209	*
VAR112	11.47	1182	*
VAR113	-6.00	1143	*
VAR114	2.28	81	*
VAR115	1.16	56	
VAR116	14.19	1218	*
VAR117	-14.18	1217	*
VAR125	6.86	1083	*
VAR126	1.74	31	
VAR127	8.07	1002	*

Note: Tests not performed for variables with samples sizes under 12.

The assumption throughout these analyses is that the POE measurement is correct and that the data for each vehicle crossing the PAT scale have been correctly aligned with the data for each vehicle weighed and measured at the POE scale. Thus, the results shown in Table 11 indicate that, statistically, the PAT system cannot be relied on to provide direct weight and spacing estimates of the corresponding POE values. However, it is important to evaluate whether the statistical differences are of "practical" importance.

In attempting to measure <u>practical</u> <u>significant</u> differences between the two scales, it is not enough to look only at the mean difference, since a small mean difference can occur in two very different ways. Table 12 illustrates this point. Notice the $\bar{d}$ values in both examples equal zero. However, in example 1 the two scales provide exactly the same measurements for a given truck, while in example 2 the scales vary in their measurements for a given truck. Thus, we must look beyond $\bar{d}$ values and examine such descriptive measures as the standard deviation of differences and the minimum and maximum differences.

An examination of descriptive measures for the difference variables in Table 10 shows that not only do the mean differences appear large, how <u>large</u> the difference is varies substantially from vehicle to vehicle. For instance, VAR109, gross weight difference, has an average difference of 2,486 pounds (4% of POE mean gross weight) and a standard deviation of 8,623 pounds. The extremes in the sample, however, ranged from -26,480 pounds to +50,860 pounds. The other variables have similar variations relative to the mean difference.

TABLE 12

ILLUSTRATIVE EXAMPLE

Case 1: Total Gross Weight

POE	PAT	d
15,000	15,000	0
25,000	25,000	0
50,000	50,000	0
88,000	88,000	0
75,000	75,000	0

$$\sum_{i=1}^{5} d = 0$$

$$\bar{d} = \frac{\sum_{i=1}^{5} d}{5} = \frac{0}{5} = 0$$

Case 2: Total Gross Weight

POE	PAT	d
15,000	16,000	-1,000
20,000	19,000	+1,000
75,000	70,000	+5,000
30,000	35,000	-5,000
90,000	90,000	0

$$\sum_{i=1}^{5} d = 0$$

$$\bar{d} = \frac{\sum_{i=1}^{5} d}{5} = \frac{0}{5} = 0$$

Therefore, our conclusion from six months' data is that from both a statistical and a practical viewpoint, the PAT scale does not provide an acceptable, direct substitute for the POE scale.

Regression and Correlation Analyses

The results of the previous analyses indicate that the PAT scale does not provide measurements which can be used as direct substitutes for the POE measurements. Also because of the variation in measurement differences from vehicle to vehicle (see Table 10), it is not possible to derive a constant adjustment to the PAT measurement to make it acceptably correspond to the true POE measure. However, the question still remains whether the PAT system provides measurements which can be combined statistically to provide acceptable estimates of the POE values. Multiple regression and correlation analyses provide a means for answering this question.

The objective of multiple regression analysis is to gather together, statistically, variables (called independent variables) which can significantly explain the variation in the dependent variable. The better the regression model is able to fit the dependent variable, the more likely it is that the model can provide acceptable estimates of the dependent variable.

In this study the dependent variable is the POE measure and the potential independent variables are variables measured by the PAT system such as weight, axle spacings, and vehicle speed. Note, a separate regression model will be developed for each POE measurement.

In analyzing the regression models, there are several considerations. First, because the regression models will be used for predictive purposes, only statistically significant independent variables will be allowed to enter the model. This means that an independent variable, in the presence of other significant variables, must be able to add significantly to the explanation of the variation in the dependent variable.

Second, the regression model will take the following form:

$$y = b_o + b_1 x_1 + b_2X_2 + \ldots + b_kX_k$$

where:

y = estimate of the dependent variable

X_i = value of the i^{th} independent variable

b_i = i^{th} regression coefficient

It is important that the signs of the regression coefficients be consistent with the relationship between the independent variable and the dependent variable. That is, if the correlation between POE axle "A" weight and PAT axle "A" weight is positive, the regression coefficient for PAT axle "A" weight in the regression model should be positive also.

Third, the coefficient of determination should be statistically significant and reasonably close to 1.0. The coefficient of determination, R^2, measures the percentage of variation in the dependent variable which is explained by the independent variables in the model. The higher the R^2, the greater the potential for the model to predict the value of the dependent variable.

Finally, the standard error of the estimate must be "small". The standard error of the estimate (SEE) measures the average variation between the true values of the dependent variable, y, in the sample data and the predicted values of y, using the values for the independent variables in the model. Thus, the SEE values need to be small in order for the weight and spacing estimates provided by the models to have an acceptable level of precision.

A rough estimate of precision is:

$$\text{precision} = \pm (2)\ \text{SEE}$$

TABLE 13

Regression Analysis Summary Statistics

(Weight Variables Only)

Variable		Overall F*	R^2	SEE	Precision
VAR07	POE A Weight	271.73	.472	851.5	$\pm$ 1703.0
VAR08	POE B Weight	91.06	.740	1781.3	$\pm$ 3562.6
VAR09	POE C Weight	220.86	.829	1582.7	$\pm$ 3165.4
VAR10	POE D Weight	508.48	.915	1341.1	$\pm$ 2682.2
VAR11	POE E Weight	594.89	.899	1480.7	$\pm$ 2961.4
VAR12	POE F Weight	844.33	.929	1145.9	$\pm$ 2291.8
VAR14	POE G Weight	2010.16	.832	7708.3	$\pm$ 15416.6
VAR73	POE BC Weight	1486.07	.805	3536.3	$\pm$ 7072.6
VAR75	POE DE Weight	2960.45	.855	3604.3	$\pm$ 7208.6

*Note: All models significant at alpha = .001

For each dependent variable, it was possible to construct a statistically significant regression model which contained only significant independent variables. Table 13 illustrates the summary data for each model. In all cases, the PAT variable corresponding to the dependent variable entered the model as a significant variable with expected positive sign. In all but two cases vehicle speed entered the model as a significant variable. In all instances, the sign on the speed variable was negative. This indicates that given two trucks of equal POE weight, the faster the truck is moving the more likely it is that the true POE weight is lower than indicated by the PAT scale.

In several models either total axle spacing or total bumper-to-bumper spacing entered as a significant variable with a negative coefficient.

With the exception of VAR07, all the R^2 values exceed .70. However, the SEE of the estimates and the corresponding precision values are not acceptable from a practical standpoint. For instance, if we were to use the regression model to estimate VAR14, POE gross weight, our 95 percent prediction interval would be approximately $\pm$ 15,416 pounds, which is much too wide. On a relative basis, the other models provide prediction intervals which are just as unacceptable.

Efforts were made to develop "better" regression models by transforming variables and by controlling for various levels of manipulation error code, with no significant improvement in the regression results.

Further Analysis

In an effort to isolate factors associated with differences between POE and PAT weights and measures, several analyses were performed. This section reports the results of these analyses.

It has been speculated that certain problems may occur during the dark hours which might increase the differentials between POE and PAT values. For instance, the Idaho Transportation Department crew involved with data collection intentionally omitted vehicles from the sample which were perceived to have not made proper contact with the PAT scale. If, during the dark hours, this visual check was impeded, it might mean that vehicles which otherwise would have been omitted from the sample were included at night. Hopefully, the manipulation error code feature of the PAT system would detect this.

To determine whether the PAT scale performed better during daylight hours than night hours, the overall sample was divided into two sub-samples based on the hours the data were collected. For this analysis, daylight was defined as 7:00 AM to 10:00 PM and dark as 10:00 PM to 7:00 AM. The daylight sample included 792 vehicles and the dark sample 426 vehicles.

Table 14 illustrates the frequency distribution for manipulation error code by daylight versus dark. A Chi-Square test was used to test whether there is a significant difference between the two samples. Based upon these data, no significant difference (Chi-Square = 10.11) can be concluded using alpha = .05.

Table 14

Manipulation Error Code

Frequency By Daylight vs. Dark

Code Description	Daylight Frequency	Daylight Percent	Dark Frequency	Dark Percent
Imbalance 10% "No Error"	47	5.9	15	3.5
Imbalance 10-19%	200	25.3	113	26.5
Imbalance 20-29%	191	24.1	116	27.2
Imbalance >29%	336	42.4	170	40.0
Speed Var. > 10%	1	.1	0	0
Imbalance 20-29% & Speed Var. >10%	2	.3	0	0
Imbalance >29% & Speed Var. >10%	3	.4	1	.2
Scattering >50%	2	.3	3	.7
Imbalance 10-19% & Scattering >50%	1	.1	0	0
Imbalance 10-19% & Scattering >50%	1	.1	1	.2
Imbalance >29% & Speed Var. >10% & Scattering >50%	0	0	1	.2
Missing	8	1.0	6	1.4
TOTAL	792	100.0	426	100.0

Manipulation Error Definitions

"Imbalance" is a measure of the difference in weights measured by the left and right side weigh pads for the same axle.

"Speed Variance" is a measure of the difference in vehicle speed calculated for different axles on the same vehicle.

"Scattering" is a cumulative measure of the imbalance among certain combinations of weigh pads.

Thus, these data do not indicate that the manipulation errors differ during daylight versus dark hours.

A similar comparison was made for pad error codes. Table 15 illustrates the frequencies by error code and light versus dark. The computed Chi-Square value is 12.51, which is insignificant at the .05 alpha level. Thus, these data do not indicate a statistical difference between pad errors in daylight versus dark.

We also looked at the absolute percentage difference for gross vehicle weight (VAR148) on a daylight versus dark basis. VAR 148 is computed as follows:

$$VAR148 = (VAR109/VAR14) * 100$$

where:

VAR109 = POE - PAT gross weight

VAR14 = POE Gross

Table 16 illustrates the frequency breakdown for VAR148 crossed with daylight versus dark. Again the Chi-Square test (Chi-Square = 7.92) failed to conclude (alpha = .05) that a difference exists in gross weight percent difference between the daylight and dark samples. Note, Table 17 discussed in subsequent paragraphs contains statistics which are somewhat contradictory of this conclusion. Further analysis involving VAR148 appears on subsequent pages of this report.

Table 15

Pad Error Code

Frequency By Daylight vs. Dark

Code Description	Daylight Frequency	Daylight Percent	Dark Frequency	Dark Percent
No error	640	80.5	336	78.9
Pad 4	116	14.6	74	17.4
Pad 3	18	2.3	7	1.6
Pad 2	2	.3	1	.2
Pads 2 and 4	7	.9	2	.5
Pads 2 and 3	0	0	2	.5
Pad 1	8	1.0	1	.2
Pads 1 and 4	0	0	2	.5
Pads 1 and 3	1	.1	1	.2
	792	100.0	426	100.0

Table 16

Absolute Percent Difference-Gross Weight

Daylight vs. Night

	Daylight		Dark	
Absolute Percent Difference	Frequency	Percent	Frequency	Percent
0-5%	485	61.2	264	62.0
5-10%	186	23.5	78	18.3
10-15%	47	5.9	29	6.8
15-40%	46	5.8	30	7.0
Over 40%	28	3.5	25	5.9
	792	100.0	426	100.0

To further analyze the daylight versus dark performance of the PAT system, descriptive measures for the difference (POE-PAT) variables were computed for daylight and dark. Table 17 illustrates the means and standard errors for each difference variable. Tests for significant differences between means were performed. Only five variables showed significant differences and for four of these it can be inferred that the differences in POE vs. PAT weights and measures were greater for the dark sample. Included in these is VAR109, gross weight difference. This somewhat contradicts the earlier Chi-Square analysis (Table 15) which concluded that the distribution of absolute percent difference for gross weight was not statistically different between the daylight and dark samples. Our conclusion, based upon Table 17 statistics, is that for the weight measurements for axle "A" (VAR96), gross weight (VAR109), tandem axles "AB" (VAR125), and tandem "DE" (VAR127) the night PAT performance was inferior to the daylight performance. Total bumper spacing (VAR117) actually was better during the night hours.

However, neither the manipulation error codes nor the pad error codes indicated that such performance difference would occur. (Refer to tables 14 and 15.)

The fact that, at least for some weight measurements, the daylight PAT versus POE differences were statistically smaller leads to a regression analysis for the daylight sample only. This analysis was patterned after the one performed for all vehicles and summarized in Table 13. We have summarized these latest regression results in Table 18.

Table 17

Descriptive Measures

Daylight vs. Dark

Variable		Daylight		Dark		Significant
		Mean	St. Error	Mean	St. Error	
VAR96	POE A - PAT A	436	38	588	60.81	- *
VAR97	POE B - PAT B	521	246	682	292	
VAR98	POE C - PAT C	575	316	799	225	
VAR99	POE D - PAT D	455	173	340	189	
VAR100	POE E - PAT E	626	185	614	206	
VAR101	POE F - PAT F	646	212	494	156	
VAR102	POE G - PAT G	541	365	693	289	
VAR109	POE Gross - PAT Gross	1903	292	3567	445	- *
VAR110	Spacing Diff AB	.316	.039	.337	.044	
VAR111	Spacing Diff BC	.044	.011	.117	.052	
VAR112	Spacing Diff CD	.242	.023	.174	.031	
VAR113	Spacing DIff DE	-.091	.016	-.053	.020	
VAR114	Spacing Diff EF	.114	.051	.069	.072	
VAR115	Spacing Diff FG	.034	.121	.141	.083	
VAR116	Total Spacing Diff	.520	.044	.698	.084	
VAR117	Total Bumper Diff	-.638	.062	-.842	.085	+ *
VAR125	Tandem Diff BC	539	145	1487	234	- *
VAR126	Tandem Diff CD	1921	1618	2619	1565	
VAR127	Tandem Diff DE	776	146	1377	215	- *

Note: - * Indicates significance at .05 alpha level with inference that Dark sample mean exceeds daylight mean.

+ * Indicates significance at .05 alpha level with inference that Daylight exceeds dark mean.

This somewhat contradicts the earlier Chi-Square analysis (Table 15) which concluded that the distribution of absolute percent difference for gross weight was not statistically different between the daylight and dark samples. Our conclusion, based upon Table 17 statistics, is that for the weight measurements for axle "A" (VAR96), gross weight (VAR109), tandem axles "AB" (VAR125), and tandem "DE" (VAR127) the night PAT performance was inferior to the daylight performance. Total bumper spacing (VAR117) actually was better during the night hours.

However, neither the manipulation error codes nor the pad error codes indicated that such performance difference would occur. (Refer to tables 14 and 15.)

The fact that, at least for some weight measurements, the daylight PAT versus POE differences were statistically smaller leads to a regression analysis for the daylight sample only. This analysis was patterned after the one performed for all vehicles and summarized in Table 13. We have summarized these latest regression results in Table 18.

A comparison of the regression results in Tables 13 and 18 shows that in most instances a numerical improvement occurs in R^2 when only the daylight vehicles are used. The same is basically the case for the standard error of the estimate (SEE) and for precision, although in a few instances the SEE actually increased for the daylight only sample resulting in a lessening of precision.

Table 18

Regression Analysis Summary Statistics

Weight Variables Only

Daylight Sample

Variable	Overall F*	R^2	SEE	Precision
VAR07	223.04	.531	826.8	$\pm$ 1653.6
VAR08	102.84	.743	1799.3	$\pm$ 3598.6
VAR09	109.82	.839	1623.7	$\pm$ 3247.4
VAR10	601.17	.941	1221.7	$\pm$ 2443.4
VAR11	462.15	.930	1328.8	$\pm$ 2657.6
VAR12	381.32	.911	1341.0	$\pm$ 2682.0
VAR14	1148.96	.853	7314.6	$\pm$14629.2
VAR73	1222.78	.837	3302.0	$\pm$ 6604.0
VAR75	1453.77	.869	3479.0	$\pm$ 6958.0

*Note, all models significant at alpha = .001

No statistical comparisons were made between the results in Table 13 and Table 18 because the magnitudes of the SEE values continued to be much larger than desired.

Thus, while for some dependent variables using daylight cases only produced models with somewhat better fit, the precision of predictions using the PAT measurements is still unacceptable.

Earlier we examined VAR148, the absolute percent difference in gross weight, in connection with the daylight versus dark samples. We also performed some cross-tabulation analysis using VAR148 with other categorical variables in an attempt to isolate the conditions which result in low percent differences in gross vehicle weight as opposed to higher percentage differences.

Table 19 shows the breakdown of vehicles in each category of variable VAR148. Note, we also combined some categories in which the frequencies were quite small. This reduced format was utilized in the subsequent analysis. For instance, in order to determine whether PAT system performance differed over time, the cross-tabulation in Table 20 was developed. A Chi-Square test (alpha = .05) led to the conclusion that there was a change over time, and the negative Kendall's Tau C indicates that over time, the PAT performance for gross weight improved by a statistically significant amount.

A similar analysis was performed by crossing VAR148 with surface condition (wet vs. dry), VAR66. The results are shown in

Table 19

Absolute Percentage Difference-Gross Weight

Vehicle Frequency Distribution

Absolute Percentage Difference	Number of Vehicles	Percent
0-5%	749	61.5
5-10%	264	21.7
10-15%	76	6.2
15-20%	32	2.6
20-25%	14	1.1
25-30%	11	.9
30-35%	7	.6
35-40%	12	1.0
Over 40%	53	4.4
TOTAL	1218	100.0

Absolute Percentage Difference Revised Categories	Number of Vehicles	Percent
0-5%	749	61.5
5-10%	264	21.7
10-15%	76	6.2
15-40%	76	6.2
Over 40%	53	4.4
TOTAL	1218	100.0

Table 20

Cross-Tabulation-VAR148 By VAR01

Vehicle Frequency

Month

Absolute Percent Difference	February	March	April	May	June	July	Total
0-5%	107	120	133	142	134	113	749
5-10%	37	51	54	44	35	43	264
10-15%	12	12	13	14	12	13	76
15-40%	19	21	7	13	7	9	76
Over 40%	16	7	4	9	6	11	53
TOTAL	191	211	211	222	194	189	1218

Chi-Square = 35.16*
Kendall's Tau C = -.048*

*Indicates significance at alpha = .05 level.

Table 21. A Chi-square test failed to conclude that moisture on the pavement made any difference in PAT performance for gross weight. The same conclusion was reached for weather condition based on a Chi-Square test for the data shown in Table 22.

Table 23 looks at the cross-tabulation of VAR148 with manipulation error code. Note, only codes 0-3 were included as the frequency of occurrence in the other code categories was extremely small. The Chi-square statistic indicated that PAT performance on gross weight was not independent of manipulation code. Kendall's Tau C was positive, indicating that as the imbalance increased, the percent difference tended to increase also. Note, regression models developed controlling for manipulation error code were slightly improved over those in which manipulation error code was not considered, but they still produced SEE values too large to be of practical use.

Table 23 looks at the cross-tabulation of VAR148 with manipulation error code. Note, only codes 0-3 were included as the frequency of occurrence in the other code categories was extremely small. The Chi-square statistic indicated that PAT performance on gross weight was not independent of manipulation code. Kendall's Tau C was positive, indicating that as the imbalance increased, the percent difference tended to increase also. Note, regression models developed controlling for manipulation error code were slightly improved over those in which manipulation error code was not considered, but they still produced SEE values too large to be of practical use.

Table 21

Cross-Tabulation-VAR148 By VAR66

Absolute Percent Difference Gross Weight	Surface Condition Dry	Wet	Total
0-5%	687	59	746
5-10%	249	15	264
10-15%	69	7	76
15-40%	72	4	76
Over 40%	47	6	53
TOTAL	1124	91	1215

Table 22

Cross-Tabulation-VAR148 By VAR68

	Weather Condition			
	Clear	Cloudy	Rain	Total
0-5%	648	71	27	746
5-10%	233	22	8	263
10-15%	63	10	3	76
15-40%	69	6	1	76
Over 40%	46	4	3	53
TOTAL	1059	113	42	1214

Table 23 looks at the cross-tabulation of VAR148 with manipulation error code. Note, only codes 0-3 were included as the frequency of occurrence in the other code categories was extremely small. The Chi-square statistic indicated that PAT performance on gross weight was not independent of manipulation code. Kendall's Tau C was positive, indicating that as the imbalance increased, the percent difference tended to increase also. Note, regression models developed controlling for manipulation error code were slightly improved over those in which manipulation error code was not considered, but they still produced SEE values too large to be of practical use.

Table 23

Cross-tabulation-VAR148 By VAR146

Manipulation Error

	No Error (10%)	Imbalance (10-19%)	Imbalance (20-29%)	Imbalance (29%)	Total
0-5%	47	232	204	249	732
5-10%	11	63	72	112	258
10-15%	1	11	20	38	70
15-40%	1	4	11	58	74
Over 40%	2	3	0	45	50
TOTAL	62	313	307	502	1184

Chi-Square = 119.95*
Kendalls Tau C = .19062*

*Indicates significance at .05 level.

Summary and Conclusions

The preceding analyses cover six months of data collection with a combined sample size of 1218 vehicles.

The general conclusions based upon the descriptive and statistical analysis are that the PAT system does not provide axle weights or axle spacings which are acceptable as direct substitutes for the POE weights and spacing measurements. Further, data collected by the PAT system, including vehicle speed and error codes, do not sufficiently explain the variations between POE values and PAT values to allow a useful estimation of the POE values.

Extensive efforts were made to identify and isolate the factors associated with the variations between POE and PAT values. Some improvement was gained by eliminating the vehicles sampled at night, but not enough to make the PAT estimates useful. Further, when vehicles with manipulation error code of zero were analyzed, further improvement was noted. However, the improvement still did not bring the precision of the estimates within a usable range. Further, only slightly over five percent of the vehicles sampled had a manipulation error code of zero.

Our findings, based on these data, infer that the PAT system fails to provide weight and spacing measurements which meet the Idaho Transportation Department's requirements for consistency in estimating the corresponding POE values.

In 1983, extended discussions with the PAT system manufacturers led to the installation of four new weighplates and a new analog board. Appendix D of this report describes the results of a follow-up study of 209 trucks weighed after these changes were made.

APPENDIX D

APPENDIX D

FOLLOW-UP STUDY

INTRODUCTION

After extensive analysis of the data collected in the initial six-month study of the PAT weigh-in-motion system, the manufacturer representatives and ITD researchers discussed the results and tried to determine what changes could be made to improve the accuracy and reliability of the system. As shown in Tables 8 and 9 of Appendix C, only 5.1 percent of vehicles in the original sample had no manipulation error code and only 80.1 percent recorder no pad error code.

The follow-up study addressed these problems by making two changes from the initial study. First, PAT replaced all four weigh-plates and the computer analog board to reduce the rate of physical errors in the system. Secondly, data collection concentrated on how closely the trucks crossed the center of the weigh plates; this provided a new variable called the pad location code.

The objectives of the follow-up study were to compare the system performance before and after these changes and to determine the significance of the pad location code in explaining differences between the dynamic weights measured by the PAT system and the POE static weights.

DESCRIPTIVE ANALYSIS

Sample data were collected for 209 trucks on April 28 and 29, 1983. Over 75 percent of these trucks were classified as type 3S-2.

Because the pad location code was assigned by visual observation, samples were taken only during daylight hours. (This also eliminated speculation about the statistical uncertainties of night sampling, discussed at length in Appendix C.) Road tubes were installed beside to weigh-plates to act as visual off-scale detectors. Cameras mounted on the overpass bridge helped observers refine the sample by eliminating trucks with excessive sway or other problems. The breakdown of trucks sampled by hour of the day is shown in Table 1.

No data were collected for any weather or road condition variables because these were relatively constant over the two day period. Also, no data were collected for axle spacings.

Data were collected for three variables which relate to how the vehicle crossed the PAT scale. The first two, manipulation error code and pad error code, were also recorded for all vehicles in the initial study. The third variable, referred to as pad location code, indicated the position of the vehicle crossing the PAT scale relative to the center of the weight pads. A code of 1 through 7 was assigned as shown in Figure 1.

Table 2 summarizes the descriptive measures for the vehicles sampled. The average speed for the 209 trucks was 52.9 miles per hour.

COMPARISONS WITH THE INITIAL STUDY

Table 3 shows the frequency of vehicles at each level of manipulation error, Table 4 shows the frequencies for pad error, and Table 5 shows the frequencies for pad location. Notice the improvement between the percentage of vehicles with no pad error in this sample (94.7%) and the initial study (80.1%). This significant increase (Z=5.10) was attributed to the installation of new weigh-plates.

For the data in this study, the absolute percentage difference in gross vehicle weights for the POE and PAT systems was computed as:

$$\text{Percentage} = \frac{\text{POE} - \text{PAT}}{\text{POE}} (100)$$

The average absolute percentage difference in gross weights, or average PAT error in absolute terms, was 5.59 percent. Table 6 shows the frequency of vehicles at various levels of absolute percentage error.

It should be noted that the new data reflected a slightly higher proportion (66%) of errors in 0-5% range that the six-month study found (61.5%) and a lower proportion of weighing errors in the over 15% category (6.2% vs. 10.1%). Further, of the 138 vehicles with 0-5% error range had pad location codes of 2-6. Finally, of the 13 vehicles with over 15% error, only 3 had pad location codes of 3-5.

Thus, while the earlier findings in the six-month study showed that manipulation error and pad error were of no specific value in identifying when the PAT scale would perform well, it now appears possible that pad location may provide such an indication. Small errors by the PAT system seem to be associated with vehicles which cross the PAT scale at or near the middle of the pads. A subsequent section of this report addresses this issue in more specific terms.

Table 7 shows the results of a statistical test performed to test the hypothesis that there is no significant difference between the average (POE - PAT) axle and gross weights "before" versus "after" the changes were made to the PAT scale. Table 7 shows the mean value for both "before" and "after" and indicates whether a statistical difference exists at the alpha=.05 level. The only significant difference occurred for axle A, where the new data actually reflected an increase in average error.

Table 8 presents the results of statistical tests to determine whether the error (POE - PAT) was statistically significant for axles A-G and gross weight. The test procedure used is known as a paired sample t-test.

These results indicate that only axle A and gross vehicle weight exhibited statistically significant average paired differences. We can conclude that, based on these new data, with respect to axle A and gross weight, the POE and PAT scales provide significantly different (alpha=.05) vehicle weights on the average. For the other axles, no such conclusion is warranted by these sample data. These latter results are substantially different than those reached in the six-month study, where significant differences were found in all cases between average POE and PAT weights. (Note that the small sample sizes for some axle weights in the latest sample may have contributed to these different results. From a statistical standpoint, the smaller sample sizes can be expected to increase the likelihood of concluding that there is no difference in average POE and PAT weight when in fact a difference exists. This is called a beta error.)

PAD LOCATION ANALYSIS

As shown in Table 5, 149 of the 209 vehicles in this sample had a pad location code of 3, 4, or 5. Because these codes represent the ideal vehicle locations when crossing the PAT scale, statistical analyses of this subset should provide useful information about the importance of pad location.

A second paired sample t-test compared the average paired differences between the POE and PAT weights for this subset, as shown in Table 9. For axle A, tandem CD, and gross weight, the data indicate a significant difference in average weights. These results match those in Table 8 for the entire sample of 209 vehicles.

The analysis in Table 10 compares the average errors for the full sample of 209 vehicles and the reduced sample of 149 vehicles with pad location codes of 3, 4, or 5. The four variables with reasonably large sample sizes showed a significant reduction in weighing errors. This implies that, at least for these axles, the pad location code is an indicator of weighting accuracy in the PAT system.

Further support for this contention is found in Table 11, which compares the mean differences in weights measured for the current sample subset and the full sample in the initial study. By contrast with the results in Table 7, the reduced sample showed significant improvement in weighing for some measurements, including gross weight.

Finally, while the average absolute percentage difference between POE and PAT gross vehicle weights was 5.59 percent for the full sample of 209 trucks, this value was 3.96 percent for the subset sample. This represents a statistically significant reduction in absolute percentage weighting error for gross vehicle weights.

EXTENDED PAD LOCATION CODE ANALYSIS

Assuming this sample of 209 trucks is representative, between 68 and 74 percent of all vehicles can be expected (at 95 percent confidence) to obtain pad location codes of 3, 4, or 5. This means at least 25 percent of vehicle data would need to be discarded as "unacceptable." By expanding the data collection to include all pad location codes of 2 through 6, the percentage of usable vehicles would be 92.5 to 95 percent (at 95 percent confidence). The analyses presented in Tables 12 and 13 study the impact of these additional data on the weighting accuracy of the PAT system.

Table 12 compares the mean differences in weights measured for the vehicles with pad location codes of 3-5 against codes of 2-6. (Notice the analysis includes only those weight variables with sample sizes sufficient to control the beta error probabilities at acceptably low levels.) Three of the four weight variables tested showed a significant increase in average weighing error for codes 2-6 over codes 3-5.

The mean differences analysis in Table 13 compares average weighing error for vehicles with pad location codes of 2-6 in the current sample against the full six-month sample. Notice the weight variables which showed significant error reduction in this analysis are the same as in Table 11.

This analysis reinforces the finding that pad location is an important factor in the accuracy of the WIM system. It also serves to illustrate the necessary trade-off between the relatively high rate of rejected data when using more restrictive pad location codes and the greater average weighing error experienced with less restrictive codes.

REGRESSION ANALYSIS

Table 14 summarizes the results of the regression analysis used to determine the relationships between the independent variables (measured POE weights) and a series of independent variables including the corresponding PAT weights, the vehicle speed, and a dummy variable indicating whether an individual vehicle had a pad location code of 3, 4, or 5. This table also indicates the precision of the estimate, approximated by + 2 (SEE).

Comparing the results in Table 14 with the regression results for data in the initial study (see Table 13 of Appendix C) shows substantial improvement in the precision for both axle A and gross weight, but little or no improvement for other weight variables. (The relatively small sample sizes for some axles may be a reason why these regression results are not more favorable.)

CONCLUSIONS

Though replacement of the PAT weigh-plates and analog board apparently caused a significant reduction in the average absolute percentage error in gross weight measurements; the full sample of 209 vehicles showed no significant reduction in average error (measured as the difference between POE and PAT weights). Restricting the sample to the 196 vehicles with pad location codes of 2 through 6, however, did result in a significant reduction in average error. Further restriction of the sample to the 149 vehicles with "ideal" pad location codes of 3 through 5 showed even more improvement in average error, but necessarily resulted in a higher proportion of rejected data. Despite these improvements, the sample error rate was still statistically significant for certain variables, including gross vehicle weight.

The multiple regression models developed from the data in this study were somewhat better than the regression results in the initial study. However, the lack of precision in the models still makes their use for predictive purposes questionable.

TABLE 1

VEHICLES SAMPLED BY HOUR OF DAY

HOUR	FREQUENCY	PERCENT
0700-0800	6	2.9
0800-0900	20	9.6
0900-1000	21	10.0
1000-1100	22	10.5
1100-1200	11	5.3
1200-1300	20	9.6
1300-1400	20	9.6
1400-1500	22	10.5
1500-1600	43	20.6
1600-1700	24	11.5
	209	100.0

TABLE 2

DESCRIPTIVE MEASURES
FULL SAMPLE

VARIABLE DESCRIPTION VALID (AXLES) CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	
POE-A Wgt	10,147	1,129	78	209
POE-B Wgt	15,136	4,078	785	27
POE-C Wgt	12,140	5,482	985	31
POE-D Wgt	12,696	4,717	861	30
POE-E Wgt	11,606	4,706	1,027	21
POE-F Wgt	8,934	3,123	1,181	7
POE G Wgt	8,085	3,776	1,238	7
POE Gross Weight	61,725	21,661	1,498	209
POE-BC Wgt	26,504	3,389	623	181
POE-CD Wgt	24,753	10,470	805	169
POE-DE Wgt	20,200	8,738	4,369	4
POE-EF Wgt	19,260	367	260	2
PAT-A	9,548	1,151	79	209
PAT-B	14,827	3,962	762	27
PAT-C	11,902	5,295	951	31
PAT-D	12,357	4,410	805	30
PAT-E	11,109	4,504	983	21
PAT-F	7,661	2,040	771	7
PAT-G	6,935	2,814	1,063	7
PAT Gross Weight	59,387	21,435	1,483	209
PAT-BC Wgt	25,885	8,460	629	181

TABLE 2 CONTINUED

VARIABLE DESCRIPTION VALID (AXLES) CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	
PAT-CD Wgt	23,639	10,258	789	169
PAT-DE Wgt	20,827	8,902	4,451	4
PAT-EF Wgt	14,720	8,980	6,350	2
POE-PAT-A Wgt	598	630	43	209
POE-PAT-B Wgt	309	1,529	294	27
POE-PAT-C Wgt	238	1,619	291	31
POE-PAT-D Wgt	338	1,850	338	30
POE-PAT-E Wgt	497	1,967	429	21
POE-PAT-F Wgt	1,272	3,146	1,189	7
POE-PAT-G-Wgt	1,150	2,563	969	7
POE-PAT Gross Wgt	2,337	6,065	419	209
POE-PAT-BC Wgt	619	2,647	197	181
POE-PAT-CD Wgt	1,113	2,606	200	169
POE-PAT-DE Wgt	-627	669	334	4
POE-PAT-EF Wgt	4,540	9,347	6,610	2

TABLE 3

FREQUENCY OF VEHICLES BY MANIPULATION ERROR CLASSIFICATION

CODE DESCRIPTION	FREQUENCY	PERCENT
Imbalance <10% "No Error"	24	11.5
Imbalance 10-19%	66	31.6
Imbalance 20-29%	57	27.3
Imbalance >29%	53	25.4
Imbalance >29% and Speed Var >10%	1	5
Imbalance >29% and Speed Var >10% and Scattering >50%	1	0.5
Missing	7	3.4
TOTAL	209	100.0

Manipulation Error Definitions

"Imbalance" is a measure of the difference in weights measured by the left and right side weigh pads for the same axle.

"Speed Variance" is a measure of the difference in vehicle speed calculated for different axles on the same vehicle.

"Scattering" is a cumulative measure of the imbalance among certain combinations of weigh pads.

TABLE 4

VEHICLE FREQUENCY BY PAD ERROR CLASSIFICATION

PAD ERROR DESCRIPTION		FREQUENCY	PERCENT
No Error		198	94.7
Pad 4		1	0.5
Pad 3		1	0.5
Pad 2		4	1.9
Pads 2 & 3		1	0.5
Pad 1		3	1.4
Pads 1 & 4		1	0.5
	TOTAL	209	100.0

TABLE 5

VEHICLE FREQUENCY BY PAD LOCATION CODE

PAD LOCATION CODE		FREQUENCY	PERCENTAGE
1		6	2.9
2		20	9.6
3		12	5.7
4		126	60.3
5		11	5.3
6		27	12.9
7		6	2.9
Missing		1	.5
	TOTAL	209	100.0

TABLE 6

VEHICLE FREQUENCY BY ABSOLUTE PERCENT DIFFERENCE

BETWEEN POE AND PAT GROSS WEIGHT

Absolute Percentage Difference		Frequency	Percentage
0-5%		138	66.0
5-10%		44	21.1
10-15%		14	6.7
15-20%		3	1.4
20% and over		10	4.8
	TOTAL	209	100.0

TABLE 7

BEFORE VS. AFTER ANALYSIS

TEST FOR SIGNIFICANT DIFFERENCE BETWEEN MEAN DIFFERENCES

VARIABLE DESCRIPTION	"BEFORE" MEAN	"AFTER" MEAN	Z	SIGNIFICANT
Axle A	490	598	-1.98	Yes
Axle B	593	309	.81	No
Axle C	692	238	1.30	No
Axle D	381	338	.11	No
Axle E	621	498	.27	No
Axle F	584	1272	-.57	No
Axle G	613	1150	-.54	No
Gross Weight	2486	2337	.306	No

$$Z = \frac{\bar{X}_B - \bar{X}_A - 0}{\sqrt{\frac{S_B^2}{n_B} + \frac{S_A^2}{n_A}}}$$

Significance (alpha=.05) $z \geq 1.96$ or $z \leq -1.96$

*Significant difference in means at .05 level where "after" mean exceeds "before" mean.

TABLE 8

PAIRED DIFFERENCE t TEST
NEW DATA - ALL TRUCKS

DESCRIPTION	MEAN	ST. DEVIATION	SAMPLE SIZE	t	SIGNIFICANT*
Axle A	598	630	209	13.7	Yes
Axle B	309	1529	27	1.05	No
Axle C	238	1619	31	.82	No
Axle D	338	1850	30	1.00	No
Axle E	498	1967	21	1.16	No
Axle F	1272	3145	7	1.07	No
Axle G	1150	2563	7	1.19	No
Gross Weight	2337	6065	209	5.57	Yes

* If significance is "Yes", it is concluded that a significant difference exists between average POE weight and average PAT weight at the .05 alpha level.

NOTE: Positive means indicate POE > PAT weight on average for the sample data.

TABLE 9

PAIRED DIFFERENCE t TEST
NEW DATA - PAD LOCATION CODE 3,4,5

DESCRIPTION	MEAN	ST. DEVIATION	SAMPLE SIZE	t	SIGNIFICANT*
Axle A	448	529	149	10.4	Yes
Axle B	6	877	19	.03	No
Axle C	-130	825	22	-.73	No
Axle D	0	1137	22	.00	No
Axle E	-105	854	14	-.46	No
Axle F		Insufficient Sample Size			
Axle G		Insufficient Sample Size			
Gross Weight	818	3009	149	3.32	Yes
Tandem BC	-17	1366	129	-.14	No
Tandem CD	510	1656	119	3.37	Yes

* If significance is "Yes", it is concluded that a significant difference exists between average POE weight and average PAT weight at the .05 alpha level.

NOTE: Positive means indicate POE > PAT weight on average for the sample data.

TABLE 10

FULL SAMPLE vs. REDUCED (3-4-5) SAMPLE

TEST OF REDUCTION IN AVERAGE ERROR

DESCRIPTION	AVERAGE ERROR POE - PAT FULL SAMPLE	AVERAGE ERROR POE - PAT 3-4-5 PAD LOCATION	SIGNIFICANT
Axle A	598	448	Yes(t=2.44)
Axle B	308	5	*No
Axle C	238	-130	*No
Axle D	338	0	*No
Axle E	497	-105	*No
Axle F	Insufficient Sample Size		
Axle G	Insufficient Sample Size		
Gross Weight	2337	818	Yes(t=3.12)
Tandem BC	619	-17	Yes(t=2.75)
Tandem CD	1113	510	Yes(t=2.39)

* Note, small sample sizes have likely accounted for the lack of statistical significance. Beta probabilities are quite high.

TABLE 11

BEFORE VS. AFTER ANALYSIS

TEST FOR SIGNIFICANT DIFFERENCE BETWEEN MEAN DIFFERENCES

PAD LOCATION CODE 3, 4, 5

DESCRIPTION	"BEFORE" MEAN	"AFTER" MEAN	Z	SIGNIFICANT
Axle A	490	448	.77	No
Axle B	593	6	2.13	Yes
Axle C	692	-130	3.16	Yes
Axle D	381	0	1.39	No
Axle E	621	-105	5.22	Yes
Axle F Insufficient Sample Size				
Axle G Insufficient Sample Size				
Gross Weight	2486	818	4.78	Yes
Tandem BC	860	-17	12.32	Yes
Tandem CD	2124	510	1.31	No

TABLE 12

PAD LOCATION CODE ANALYSIS

(3-5) vs.(2-6)

(POE - PAT) WEIGHTS

DESCRIPTION	CODE 3-5 MEAN DIFFERENCE	CODE 2-6 MEAN DIFFERENCE	*SIGNIFICANT
Axle A	448	555	Yes
Gross Veh. Wt.	818	1491	Yes
Tandem BC	-17	268	No
Tandem CD	510	828	Yes

*Note: If significant is Yes, this indicates that a difference in average weighing error is present.

TABLE 13

BEFORE VS. AFTER ANALYSIS

TEST FOR SIGNIFICANT DIFFERENCE BETWEEN MEAN DIFFERENCES

PAD LOCATION CODES 2, 3, 4, 5, 6

DESCRIPTION	"BEFORE" MEAN	"AFTER" MEAN	Z	SIGNIFICANT*
Axle A	490	555	-1.22	No
Axle B	543	0	2.38	Yes
Axle C	692	-103	3.24	Yes
Axle D	381	-19	1.68	No
Axle E	621	-53	2.83	Yes
Gross Weight	2486	1491	2.69	Yes
Tandem BC	860	208	3.12	Yes
Tandem CD	2124	828	1.05	No

*NOTE: If "Yes" this indicates that a difference in average weighing error is present.

TABLE 14

REGRESSION ANALYSIS SUMMARY STATISTICS

DEPENDENT VARIABLE	OVERALL F*	R	S.E.E.	PRECISION
POE Axle A Weight	245.61	.78	530.9	±1061.8
POE Axle B Weight	57.39	.88	1488.5	±2977.0
POE Axle C Weight	116.98	.93	1544.5	±3089.0
POE Axle D Weight	53.64	.86	1857.9	±3715.8
POE Axle E Weight	47.36	.89	1669.4	±3338.8
POE Gross Weight	983.62	.93	5561.06	±11122.1

*All Regression models are significant at the alpha = .001 level.